THE COMPLETE MICROWAVE OVEN SERVICE HANDBOOK

OPERATION, MAINTENANCE, TROUBLESHOOTING, AND REPAIR

J. Carlton Gallawa

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The Complete Microwave Oven Service Handbook

Operation, Maintenance, Troubleshooting, and Repair

J. CARLTON GALLAWA

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To ensure accuracy, it is quite common for manufacturers' service literature to undergo updates and revisions. Some of the illustrations used in this book were reproduced (with permission) from service literature that may subsequently be revised or updated. For that reason, it should be emphasized that, when servicing a particular product, the manufacturers' *current* servicing literature should ultimately be consulted for specific information on that product.

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Contents

Preface

MICROWAVE OVENS with their speed, convenience, energy-efficiency and elaborate features, have brought a new dimension of cooking into millions of households and commercial establishments. With their unique blend of the electrical and the mechanical, the high-voltage circuit and the high technology of computer electronics, they also bring new challenges as well as opportunities to those who are called upon to repair them. *THE COMPLETE MICROWAVE OVEN SERVICE HANDBOOK* is therefore addressed to those who are interested in, or already involved in, the service and repair of microwave ovens. It is the purpose of this textbook to help meet the challenges of safe, efficient and effective microwave oven repair. It is the further goal of this book to help individuals take advantage of the opportunities opened up by this relatively new and high-demand field of repair. This is achieved through information and instruction enabling one to gain a thorough working knowledge of each component, its construction and relative purpose in the system. A comprehensive troubleshooting guide with problems and related symptoms peculiar to individual makes and models, as well as appropriate corrective measures, will prove to be a valuable reference. A list of commonly overlooked wear-related problems such as cracking, breaking, warping and deteriorating, along with applicable preventive maintenance procedures will mark the difference between a mere repair and true *service.*

METHOD AND STRUCTURE

The method of instruction is a progressive description and explanation of the components that make up a microwave oven. Knowledge of their construction, operation, purpose, and their overall relationship and effect, will result in effective troubleshooting by recognizing symptoms unique to, or most likely caused by, a particular component. The text is organized into five parts: Part 1, *Introduction to Microwave Energy;* Part 2, *Preparing to Repair Microwave Ovens;* Part 3, *Descrip-*

tion; Part 4, *Component Tests, Failures, and Corrective Actions;* Part 5, *Troubleshooting By Symptom, Make, and Model;* and *Appendices.*

Throughout the book an attempt has been made to keep the language simple. However, certain technical words and phrases are at times unavoidable. These terms are italicized, and generally explained in either the text, the glossary, or both. Also, considerable emphasis has been placed on the use of illustrations in the hopes of providing a maximum amount of information with a minimum of confusion.

The organization and development of this text was derived from the following: (1) technical service and training manuals, (2) technical bulletins that reflect the evolution of the microwave oven industry by identifying, isolating, and subsequently solving the problems that emanated as the industry progressed, (3) Naval education and training textbooks, and (4) on-the-job training procedures, with proven principles worked out through many years of experience, providing the primary source for the context, development, and organization of this text.

RECOMMENDED SKILLS AND TRAINING

The book starts with the assumption that the student has an understanding of fundamental electrical and mechanical principles, then develops and applies these basic concepts to the operation of the microwave oven. An individual with prior experience in either electronic or mechanical troubleshooting would be well suited for this work. Experience in both would be ideal. There are, however, some other qualities that are equally, if not more, important than experience or IQ: common sense, dexterity of the hands, alertness, and keen observance are absolutely essential to the success and to the safety of the servicer. Common sense can be developed into the ability to logically analyze and interpret given factors, drawing conclusions that result in a systematic solution. The ability to use the hands effectively allows for the delicate removal of a sensitive microprocessor from a printed circuit board, or the careful maneuvering of an eighteen-pound transformer through a nest of wires and around sharp edges that are there to punish the awkward or the hasty. Being alert and observant means making good use of the senses. Isolation of many, if not most, problems begin with the input supplied from our *inherent* troubleshooting equipment, our *eyes, ears,* and *nose.*

EXPLANATION OF SOURCES OF INFORMATION

Since 1977 there have been many occasions when communication with the engineering staff or the technical service representatives of the various manufacturers became necessary. On these occasions, careful notes were kept in order to fully benefit from suggestions, solutions, and explanations. These notes form one of the sources of information for this textbook. Factory-sponsored service schools have also provided varying degrees of enlightenment which, along with numerous service manuals, service letters, and technical bulletins, add further input to this material. A compilation of typical, and not so typical, symptoms, problems, and solutions, based on the aforementioned and combined with many years of practical experience, furnish the final source of reference information and material for this text.

THE AUTHOR'S BACKGROUND

J. Carlton Gallawa is a graduate of the U.S. Naval Surface to Air Missile Fire Control Technician School Class A, Phases I and II and Class C. This involved the operation, testing, maintenance and repair of simulated shipboard missile fire control systems including weapons direction systems, missiles and associated support equipment. He is also a graduate of the Washington School of Drafting, specializing in mechanical technology concepts and electro-mechanical drafting. Mr. Gallawa worked for several years as a quality control engineering technician for an electronic data communication company. During this assignment he designed test components, formulated test procedures, and effected significant modifications to various data transmission, video switching, and remote control supervisory equipment. In 1971 he began repairing commercial microwave ovens for a company in the vending industry, and while in this capacity he formulated and wrote a course of instruction on microwave oven operation. In 1977 he established a business specializing in the service and repair of *microwave ovens,* eventually contracting with most major manufacturers as a factory authorized commercial and residential warranty servicer. Since that time Mr. Gallawa has had extensive experience in this field involving virtually every type of microwave oven ever manufactured. This also included the participation in and completion of numerous technical service schools and seminars provided by manufacturers including SHARP, AMANA, LITTON, TAPPAN, PANASONIC, QUASAR, and MAGIC CHEF.

ACKNOWLEDGMENTS

The author wishes to express grateful appreciation to his parents, Jack and Gerrie Gallawa for their many suggestions and corrections that aided in simplifying and clarifying the wording of this entire text. Special appreciation is extended to the author's wife and two sons whose cooperation, forebearance, and support contributed significantly to the completion of this book. The kind help and encouragement of many friends in many different ways is also thankfully acknowledged.

Introduction to Microwave Energy

Part 1

"Who invented microwaves anyway?" is a question you will hear quite often. That is like asking who invented electricity. There is another point of concern that is often expressed after the outer cover of the oven has been removed. The observer, having strategically withdrawn to the perceived safety of the next room, inquires, *"Aren't you afraid of radiation poisoning?"*. Some are concerned, too, about how long the microwaves stay in the food after cooking, and if microwave emissions cause cancer. And, of course, there's the *"did-you-hear-about-the-person-who-dried-the-cat-in-a-microwave-oven?"* story. If this feline misfortune is indeed factual (although, to date, there exists no documentation to substantiate such an absurdity) there is one thing for certain; it is *not* the microwave oven that need be feared. The question is; how would you, as the technician and therefore the authority, respectfully reply to questions like these? The first part of this book will provide the information necessary to set the fearful at ease, inform the misinformed, and intelligently respond to common questions with authority. *Chapter One* outlines the invention and development of the microwave oven. *Chapter Two* discusses the principles of microwave energy, as opposed to radioactivity, and the relative position of both in the frequency spectrum. *Chapter Three* consists of a brief and objective consideration of the safety and danger aspects of microwave energy as it pertains to the microwave oven.

A Brief History of Microwave Oven Development

chapter 1

Like many of the great inventions that become today's conveniences and tomorrow's necessities, the MICROWAVE OVEN is, in fact, a by-product of another technology. It was during a *radar*-related research project around 1946 that Dr. Percy Spencer, an engineer with the Raytheon Corporation, noticed something very unusual. He was testing a new vacuum tube called a magnetron, when he discovered that the candy bar in his pocket had melted. Intrigued, and perhaps wondering if the chocolate bar had been the only casualty of these permeating waves, Dr. Spencer tried another experiment. This time placing some popcorn kernels near the tube and, perhaps wisely, standing a little farther away, he watched with an inventive sparkle in his eye as the popcorn sputtered, crackled, and popped all over his lab.

The next morning, Scientist Spencer decided to put the magnetron tube near an egg. Spencer was joined by a curious fellow-scientist, who watched intently as the egg began to tremor from increasing internal pressure caused by the rapid temperature rise of its contents. Evidently, the curious colleague moved in for a closer look just as the egg exploded and splattered hot yoke all over his amazed face. The face of Spencer lit up with a logical scientific conclusion; the melted candy bar, the popcorn, and now the exploding egg, were all attributable to exposure to low-density microwave energy. And, if an egg can be cooked that quickly, why not other foods? Experimentation began.

Dr. Spencer fashioned a metal box with an opening into which he fed microwave power. The energy entering the box was unable to escape, therefore creating a higher density electromagnetic field. When food was placed in the box and microwave energy fed in, the temperature of the food rose very rapidly. Dr. Spencer had invented what was to revolutionize cooking and form the basis of a multimillion dollar industry, the *microwave oven*.

Engineers went to work on Spencer's invention, developing and refining it for practical use. By late 1946, the Raytheon Company had filed a patent proposing that microwaves be used to cook food. An oven that heated food using microwave energy was then placed in a Boston restaurant for testing. In 1947 the first commer-

cial microwave oven hit the market and the "heat" was on—or was it? These primitive units were large and cumbersome, standing five and a half feet tall and weighing 175 pounds. The magnetron tube had to be water-cooled, so plumbing installations were required. They were also very expensive, costing about $5,000 each, and one can only imagine the frustrations in working with these temperamental behemoths.

There was a great deal of reluctance, on the part of many, concerning these first units and, not surprisingly, they were not too readily accepted. Initial sales were disappointing. However, further improvements and refinements produced a more reliable and lightweight oven that was less expensive, and a new *air*-cooled magnetron eliminated the need for a plumber. Eventually, the microwave oven reached a relative level of acceptance, particularly by the *vending industry*.

Vendors had the problem of having to *keep* foods hot until they were purchased or until they went bad, which was obviously wasteful and expensive. By having the microwave oven available, they were able to keep the products refrigerated up to the point of service, then they could quickly heat up the food in the microwave oven. This resulted in fresher food, less waste, and money saved.

Soon, the restaurant industry realized that the microwave oven solved more problems than it created. Faced with essentially the same problem, keeping foods hot for extended periods of time, restaurant owners began to appreciate the value of the microwave oven in their operations. Now they could keep their foods refrigerator-fresh and then heat to order.

As the food industry began to recognize the full potential and versatility of the microwave oven, it was put to new and varied uses. Industries began using microwaves to dry potato chips and roast coffee beans and peanuts. Meats could be defrosted, precooked and tempered. Even the shucking of oysters was made easier by microwaves. Other industries found the diverse applications of microwave heating quite advantageous. In time, microwaves were being used to dry cork, ceramics, paper, leather, tobacco, textiles, pencils, flowers, wet books and match heads. Microwaves were also used in the curing process of synthetic materials such as nylon, rubber, and urethane.[1] The microwave oven had become a necessity in the commercial market and the possibilities seemed endless.

Technological advances and further development led to a microwave oven that was polished and priced for the *consumer* kitchen. However, there were many health-related myths and fears surrounding these mysterious new electronic "radar" ranges, so the boom was somewhat belayed, but not for long. By the seventies, more and more people were finding the benefits of microwave cooking to outweigh the possible risks, and none of them, it seemed, were dying of "radiation" poisoning, going blind, sterile, or becoming impotent (at least not from using microwave ovens). As fears faded, a swelling wave of acceptance began filtering into the kitchens of America, melting away myths and turning doubt into demand. The boom had begun.

By 1975, sales of microwave ovens would, for the first time, exceed the number of gas ranges sold. The following year, a reported 17% of all homes in Japan were doing their cooking by microwaves, compared with four percent of the homes in the United States the same year. However, by 1978, microwave ovens were adorning the kitchens in over nine million homes, or about 14% of all homes in the United States. By the end of 1980, this would increase to more than 25%. In 1986, the microwave oven became a more commonly owned kitchen appliance than the dishwasher, reaching nearly 60%, or about 52 million U.S. households. America's cooking habits were being dramatically changed by the time and energy-saving convenience of the microwave oven. Once considered a luxury, the microwave oven

[1]Paul Brodeur. *The Zapping of America*, [Norton, 1977] p. 9.

has developed, through modern technology and popular demand, into a practical necessity for a fast-paced world. An expanding market has produced a style to suit every taste, a size and shape to fit every kitchen, and a price to please almost every pocketbook. Options and features, such as the addition of convection heat, probe and sensor cooking, meet the needs of virtually every cooking, heating or drying application. Today, the magic of microwave cooking has radiated around the globe, becoming an international phenomenon.

Inventor Spencer continued at Raytheon as a senior consultant until he died at the age of 76. At the time of his death, Dr. Percy Spencer held more than 100 patents and was considered one of the world's leading experts in the field of microwave energy, despite his lack of a high school education.

Basic Principles of Microwave Energy

chapter 2

2.1 INTRODUCTION

Microwaves are very short, invisible electromagnetic waves of energy that travel at the speed of light, which is 186,282 miles per second. Electromagnetic waves can be illustrated by tossing a pebble into a quiet pond. The pebble striking the still surface of the water creates a disturbance. The disturbance causes the water to move up and down in the form of ripples which radiate in ever-widening circles over the surface of the pond (Fig 2–1). These ripples, or vibrations, rising and falling away from the point where the pebble hits the water are called *waves*. Because these waves move up and down at right-angles (or perpendicular) to the direction they are traveling, they are called *transverse* waves (Fig. 2–2). Electromagnetic waves are examples of transverse waves.

Figure 2-1 How a pebble creates wave motion to the surface of a pond. (Courtesy of Michael S. Wagner)

were to disrupt or distort that energy pattern it would produce undesirable results, such as *arcing* and *backfeeding*.

2.9 ARCING AND BACKFEEDING

As the reasons why metallic substances cause arcing in a microwave oven are examined, it will also become clear why some metal objects may be used *without* causing any such problems.

Metallic objects that are indiscriminately placed in a microwave oven cavity will disrupt and distort the energy pattern. This produces two results, *arcing* and *backfeeding*. Arcing results when two metal objects, such as a metal bowl and the [metal] cavity wall, are placed in close proximity and subjected to an intense field of microwave energy. The air between them becomes electrically charged, just as the air between a thundercloud and the earth. This ionized air becomes an electrical conductor, and current then leaps the gap like a small bolt of lightning. However, lightning only lasts for an instant because it discharges or neutralizes the ionized air, but an arc in a microwave oven will continue, to a greater or lesser degree, as long as energy is applied. At the very least this can cause pitting or marring of involved surfaces, and at worst, can burn a hole right through the cavity wall.

Why do some cookbooks suggest the use of tin foil in certain applications, and how can "TV dinners" (with tin foil plates) be "microwaved" without arcing? The answer lies in proper placement and positioning. The correct use of metal and the extent to which it may be used will be outlined in the literature that accompanies models which are designed to allow such use. Metal objects, including the [optional] temperature probe with its stainless steel shaft, must be kept clear of walls, floor and door, as well as each other. Metallic substances used in a microwave oven must also be of a *continuous* nature. For example, a plate with gold or silver trim will arc around the trim when exposed to microwave energy, usually resulting in a broken plate. Why the arcing? Because, if a magnifying glass were held up to the trim work it would reveal tiny cracks in the gold or silver paint. The microwaves arc across these microscopic gaps.

However, too much metal, or operating a microwave oven when the cooking cavity contains nothing (*no-load*) capable of absorbing microwave energy, creates the second result, *backfeeding,* a potentially damaging development. Large metal objects, too many small metal objects, or operating an oven empty, will cause the energy to reflect back, or *feed back* to the *magnetron tube*. The magnetron does not want this energy back, and it tends to dissipate these returning waves in the form of heat. This excess heat reduces the efficiency of the magnetron and shortens its life. Long periods of unchecked backfeeding will cause permanent magnetron failure.

It should be noted that no-load operation can also result in excessive RF leakage around and through the door, as well as through the air and light vent holes.

Metal racks designed for use in microwave ovens *do not* cause arcing or backfeeding because they are *tuned* to the cavity. When properly installed, the rack acts as an energy *grid,* allowing a lesser amount of energy to filter through to the lower cavity area, while maintaining a higher concentration of energy in the upper portion. The metal rack effectively divides one cavity into two, each with different concentrations of energy which emanate from the same source.

Burn tracks along the cavity walls or along the inner surface of the door are generally the result of arcing which is caused by operating the oven with nothing inside the cooking cavity except the metal rack. Or, the metal rack has been installed improperly. In either case, customer education would be in order.

Safety of Microwave Energy – An Objective Discussion

chapter 3

3.1 INTRODUCTION

> In 1926, Soviet naturalist Vernadskii wrote, "We are surrounded and penetrated, at all times and at all places, by eternally changing, combining, and opposing radiations of different wavelengths." He was referring to electromagnetic radiation emanating from the sun and other sources in earth's galaxy that finds its way into our atmosphere. Vernadskii had no way of knowing that within fifty years his observation would apply as well to radiation generated here on earth by his fellow man.—Paul Brodeur, *The Zapping of America,* (Norton, 1977) p. 15.

Since the development of radar, man's ability to generate and harness microwaves has resulted in such a proliferation of devices using microwaves that today virtually everyone on earth is affected by them to some degree. Some environmentalists call it "electronic smog," and one United States government agency warned that the levels Americans are exposed to every day, without even being aware of it, may be dangerous.

Particularly in some urban areas, microwave and related radiation is estimated to be up to a billion times or more as great as that which naturally exists in the environment. And sources of this kind of radiation are increasing rapidly.

Airports have navigational systems that use microwaves, and police radar operates on microwave frequencies. Television, telephone, and computer signals are transmitted by microwaves. Broadcasting, surveillance, and communications satellite systems utilize microwaves, as do some air pollution monitoring systems. Motorist-aid call boxes along the highway, many burglar alarm systems, and some automatic garage door openers work because of microwaves.

The world of medicine uses them for sterilization, to retard tumor growth, and to treat sore muscles. Industry and science each have their own uses for microwaves. Researchers in Canada have developed an aircraft that can stay aloft for months at a time without fuel. The plane is powered by electricity which is beamed up as

microwave energy, then converted back into electrical energy which powers the engine. The military, by far the largest users of microwave devices in today's world of electronic warfare, employ microwaves for such things as guidance systems for nuclear missiles and antimissile missiles, range finders for tanks, and for eavesdropping.

> The Soviets allegedly used microwaves to irradiate the American Embassy in Moscow. Conversely, American warships would, reportedly, pull alongside Russian surveillance trawlers on the high seas, turn on their radars at full megawatt power, and "paint" the Soviet vessels with radiation. This would burn out the trawlers' electronic listening devices, and probably accounts for the fact that Russian sailors were seldom seen on deck.—Paul Brodeur, *The Zapping of America,* (Norton, 1977) p. 308.

This era of *energy pollution* has brought about growing concern regarding the potential risks involved in exposure to low-level microwave radiation, in particular from microwave ovens, the most common consumer use of microwave energy. With the skyrocketing popularity of microwave ovens, some are seriously questioning the wisdom of bringing these microwave-emitting devices into our homes when the effects of microwaves on the human system are not yet completely understood. Extensive research that began particularly in the mid-1970's in the United States, and as far back as the 1930's in Russia, is now rendering some interesting and controversial results.

3.2 MICROWAVES—HOW DANGEROUS ARE THEY?

If microwaves in an oven can cook a piece of beef, they will also have the same effect on human tissue if exposed to high enough intensities for a long enough period of time. Certain body organs are particularly sensitive to this *thermal* effect. Thermal means heat. Just as it is the heat produced by a hot stove that causes the careless cook to voice a sudden unsavory expletive, so too, it is the heat generated by the microwaves that creates the hazard in this case. For example, if the lens of the eye were exposed to excessive heat from microwaves, its circulatory system would be unable to provide sufficient cooling, and it would cook like the white of an egg. Exposure to high levels of microwaves can cause cataracts. Also, the stomach, intestines and bladder are especially sensitive to thermal damage from high levels of microwaves. Likewise, the testes are very sensitive to changes in temperature, since sperm can be formed only at temperatures lower than that of the body itself. Thus, accidental exposure to high levels of microwave energy can alter or kill sperm, producing temporary sterility. The question is: How intense would levels of microwave energy have to be to create such a danger?

3.3 MEASURING MICROWAVES

The power density of microwaves is determined by measuring the amount of energy that flows through one square centimeter (a square centimeter is about the size of an aspirin tablet) of space in one second. Western scientists believed that serious injuries could result only at levels of 100 MilliWatts per square CentiMeter (mw/cm^2) or higher. It was theorized that a built in safety factor of 10 times would be a safe margin. So, in the mid-1950's a voluntary industry standard of 10 mw/cm^2 (or, one-tenth of 100 mw/cm^2) was adopted.

In 1971, due to the concern of the Department of Health, Education and

Welfare (now the Department of Health and Human Services), the standard for allowable leakage from microwave ovens in the United States was set by law to the present, more stringent, levels of *1mw/cm²* (at a distance of five centimeters — see Section 15.7) prior to acquisition by a purchaser, and *5mw/cm²* thereafter. These safety standards were based on the belief that the only danger from exposure to high-intensity microwave energy was a thermal or overheating effect.

3.4 SOVIET STANDARDS

In the U.S., exposure standards were being developed mainly under the American National Standards Institute by a broad group of scientists and by representatives of users and manufacturers. While in East European countries and, in particular, Russia, the exposure standards were being determined by a specialized research institute on occupational health. Rather than concentrating on the effects of high-intensity levels, Soviet scientists were focusing their efforts on the lesser-known effects of prolonged or repeated exposure to low levels of microwaves. Their research, which began quite some time before that of their Western counterparts, has yielded some rather unsettling reports. Soviet studies show that long-term exposure to low levels of microwave energy could result in unpleasant effects that are not attributable to over-heating (or thermal effect) alone. These effects could be seen at exposure levels at and *below* 10mw/cm², which is the occupational *safety standard* in the U.S.

The U.S.S.R., and other European countries, have thus set their own strict guidelines for microwave safety, concluding that Western safety standards are simply not safe. For example, Russian workers are required to wear protective goggles any time they are temporarily exposed to a microwave radiation level of 1mw/cm², a level routinely allowed to leak (although in recent years, rarely does) from U.S. microwave ovens.

These reports have provoked a reexamination of Western safety standards and heightened experimentation. Several American laboratories have since found low-level exposure to microwaves to cause *cumulative* harmful effects on the eye, such as cataracts. (Cumulative means that one low-level dose in itself would not be enough to affect you, but if you add another and another, and so on, then eventually the effects would be seen.) Research also reports a reduction in personnel efficiency, and in the ability to perform certain tasks, and even a possible link to cancer. Thus, while not all the research is complete, there has been enough evidence in support of Soviet findings to likely cause an eventual toughening of U.S. standards.

3.5 WHAT ARE SAFE LEVELS OF EXPOSURE?

No one really knows for sure how to interpret the emerging results as painstaking experimentation continues. One thing they do know, however, is that there is a *non*thermal effect from microwaves at levels that many people may be exposed to on a daily basis. What degree of danger does this nonthermal effect represent? The answer to that has to do with the controversial difference between a simple biological *effect* and a serious biological *hazard*. For example, a reduction in the ability to perform certain tasks may be the effect, but at what point does that effect constitute a hazard?

So, what are safe levels of exposure to microwaves? While vigorously warning of the invisible dangers involved with nonionizing radiation, Dr. Milton M. Zaret, a professor of ophthalmology, and a long time student of the biological effects of microwaves, answers: "I have no idea what a safe level is, I don't think anyone in the world knows what a safe level is."

The effects of long term exposure to low levels of microwaves, and their significance to human health, will become clear only after large numbers of people who are being exposed to microwaves are studied for many years. Studies are being done with animals, but it is difficult to translate the effects of microwaves on animals to possible effects on humans. For example, researchers find it quite difficult to simulate the conditions (with animals) under which people use microwave ovens. Since no one can say with certainty what levels of exposure are safe, the course of wisdom would be, as a U.S. government spokesman pointed out, to avoid "exposure to any unneeded radiation."

3.6 HOW FAR AWAY IS SAFE?

One pertinent characteristic of microwaves is that they disperse and dissipate very quickly in the atmosphere. For example, the maximum allowable leakage from a microwave oven (after the sale) is 5 milliwatts of microwave radiation per square centimeter at approximately 2 inches from the oven surface. However, as Figure 3-1 illustrates, as you move away from the oven, the level of exposure to any energy that may be leaking decreases dramatically. This may be likened to holding your hand immediately above a burning candle as opposed to 4, 8 or 12 inches away. Say you are standing 2 inches away from a microwave oven, and are being "zapped" by

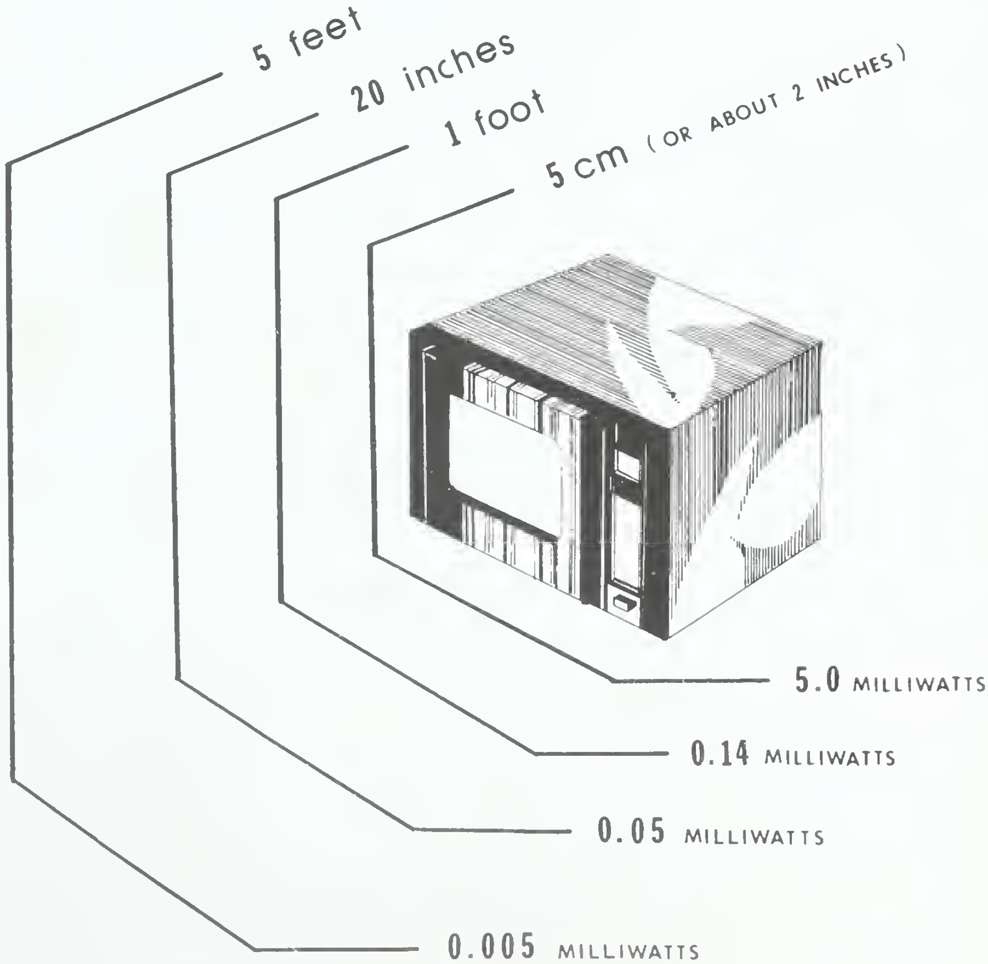


Figure 3-1 Exposure levels decrease dramatically as the distance increases. (Courtesy of Michael S. Wagner)

$5mw/cm^2$ of microwave energy, then you wisely step back to a distance of 20 inches or roughly an arm's length. Your level of exposure would drop by a factor of 100, (the square of the distance) to $.05mw/cm^2$, a level compatible even with stringent Soviet standards, (present Soviet occupational standard allows up to 0.1mw/cm in no more than two hours). However, it must be noted that Czech scientists have reported some effects even at these infinitesimal levels. This, combined with the opinion of Russian scientists, that microwave effects are cumulative, certainly underscores the need for consumers and servicers alike to observe certain common sense precautions.

- Stay **at least** an arm's length away from the front of an operating oven. This is especially so with pregnant women according to a U.S. government agency, which states that the human fetus is "probably the most sensitive segment of the population potentially exposed to microwave radiation." Children represent another sensitive segment of the population. Never should anyone, and *especially* children, stand gazing into, or directly against an operating microwave oven.
- If the door of an oven will not close properly, is bent, warped, tampered with, or otherwise damaged in any way, DO NOT OPERATE the oven unless you are a qualified servicer with an approved RF survey meter in hand.
- Never operate an oven when it is empty. This creates a no-load condition which can damage the oven and cause excess leakage.
- Never inactivate, interfere with, or try to adjust the built-in safety interlock system of an oven, *unless* you are properly equipped and qualified to do so. Tampering with safety interlocks would be as foolish as disconnecting the brakes on a car.
- The Food and Drug Administration recommends that microwave ovens not be used in home canning. It is believed that they do not produce or maintain temperatures high enough to kill harmful bacteria.

Observing these safety suggestions, as well as others that will be presented in subsequent chapters of this book, will help to minimize exposure levels and the risk of serious accidents.

—Our thanks to the publishers of AWAKE! magazine. Much of the preceding information was adapted from the 3/22/81 (pp. 13–15), 4/22/81 (pp. 12–15), and 5/22/81 (pp. 27–28) issues of AWAKE!

3.7 MICROWAVES AND CARDIAC PACEMAKERS

It has been a subject of great concern, especially for many heart patients, that stray leakage from microwave ovens could interfere with the proper operation of their cardiac pacemakers. The fact is, there are at least 20 other known sources of electromagnetic interference which could also cause a pacemaker to malfunction—if it were *non-shielded.* RF interference is generated by such common items as: electric shavers, auto ignition systems, walkie-talkie radios, fluorescent lights, and dial telephones. Many more of these electronic interference-emitting products are commonplace items even in hospitals; diathermy, electro-surgical units, electric bed motors, elevators, personnel pagers, electric heaters and heating pads, to mention a few.

The problem has been resolved, for the most part, with the development of a new *shielded* pacemaker. Since microwaves, or any other type of electronic interference, cannot penetrate their stainless steel casing, the possibility of harm to

people who wear these modern heart pacemakers is extremely remote. In an effort to determine the overall susceptibility of these units to electromagnetic interference, U.S. government agencies contacted all known U.S. manufacturers of cardiac pacemakers. Their findings indicate that less than 1% of all pacemakers are sensitive to electronic interference, and this number is rapidly decreasing. Apparently, the *external demand* type of pacemaker continues to be a particularly sensitive device, so wearers of this type of pacemaker should avoid all possible sources of electronic interference. In fact *all* patients with pacemakers would *be well advised* to contact the manufacturer of the unit *and* consult with their physicians for the final word on this matter.

While signs that warn “MICROWAVE IN USE” are not a federal requirement, local administrations or establishment owners may prefer to display such signs for various reasons. For example, some may display warning signs for their own protection (like a “watch your step” sign), to avoid the possible psychological trauma that could be suffered by an unwary pacemaker patient who suddenly discovers that he is sitting next to an operating microwave oven.

3.8 RADIATION INJURIES FROM MICROWAVE OVENS?

A 1986 report on microwave oven radiation by, among others, the Food and Drug Administration, has this to say: “There have been allegations of radiation injury from microwave ovens. The injuries known to FDA, however, have been injuries that could have happened with any oven or cooking surface. For example, people have been burned by hot food, spattering grease, or steam from food cooked in a microwave oven.

3.9 COLOR TELEVISION EMISSIONS

While not necessarily related to microwave safety, these types of emissions merit brief consideration because they are in the same family as microwaves, and are very often the subject of consumer concern.

Emissions from color TV sets are of the nature of X-rays which are more serious and penetrating than low-level microwaves. However, modern circuitry improvements, combined with the stringent regulatory control of the Food and Drug Administration (FDA), have brought color TV emission levels to below that of certain natural background radiations. Just as there is a greater risk of excessive leakage from older, or improperly serviced, microwave ovens, so too, the same potential hazard exists with color television sets. In either case, it would be the course of wisdom to observe appropriate precautions. Use discretion when buying a used color TV set or microwave oven. Selection of a repairman should be done with scrutiny. And, sit or stand no closer to the unit than is necessary.

A Final Word

As with so many modern conveniences, the benefits must be weighed against the hazards, the risks against the rewards. Sometimes this can be a delicate and a controversial balance. So while these devices must be used at one’s own risk, the application of common sense and caution will certainly minimize the risk factor in this balance. A growing knowledge and understanding of electromagnetic radiation is producing a better perspective, enabling a more clear definition of just what the balance is in each case and allowing each person to draw his or her respective conclusions accordingly. Meanwhile, the controversy, the debate, and the research continue.

And, *so* do the repairs . . .

Preparing to Repair Microwave Ovens

Part 2

In order to be fully equipped and prepared to enter into the field of microwave oven repair, *Chapters Four, Five* and *Six* provide many necessary on-the-job safety considerations, as well as outlining proper and safe working conditions. In addition, there is a complete and descriptive list of tools and equipment, ranging from the recommended to the required, the necessary to the specialized, the ordinary to the homemade, and the useful to the useless. *Part 2* concludes with some helpful professional observations concerning proper demeanor when rendering "in-home" service.

Safety Considerations

chapter 4

4.1 INTRODUCTION

As with any electrical appliance, certain safety precautions must be observed. Microwave ovens are unique in that there are several different areas where caution must be exercised. First, and typical with most appliances, is the *line* or *supply voltage*; this is usually 115 volts AC (alternating current), and in the case of many commercial units, 208 to 240 VAC. The latter is developed across two "hot legs" or phases, and 208 to 240 VAC is measured between these two points. A third (center) wire is the ground or neutral. A measurement from this neutral point to each "hot leg" should produce 115 VAC $\pm$ 10%. Usually each "hot leg" is protected by a line fuse (or circuit breaker), so a measurement of only 60 to 90 VAC from either leg to ground, or of only 115 VAC between the two "hot legs", likely means that the fuse (or breaker) on one side or the other has opened.

Second is the section where the line voltage is stepped up to thousands of volts. This aptly called *high-voltage section* obviously commands extreme caution. Third, are the various containment components that serve to keep the microwave energy inside the oven, where it belongs. Then a fourth area concerns the safe handling and lifting of these unwieldy appliances which are generally lop-sided, cumbersome, handle-less, sharp-edged, and often grease-slippery.

Know the safe way to do things, then *develop habits consistent with this knowledge.*

4.2 SAFETY AROUND LINE VOLTAGE

Most problems can be detected merely with careful observation, without the power connected. However, at times it does become necessary to make certain checks with the power on. It is for these occasions that certain safety habits *must* be developed. If you have experience in troubleshooting electrical appliances, some of these may

be familiar steps; however, associated high-voltage circuits in a microwave oven make them life-saving steps.

I. FIRST and ALWAYS, before attempting any repairs or checks, *make certain the unit is NOT plugged in.*

A. Visually and, if there are other cords tangled around it, *physically follow* the power cord until you find the plug itself. A plug in the hand is better than a shocking, damaging, and embarrassing surprise. Make this a habit, just as you would check for your keys or your wallet—*track down* the power plug *before* you ever put your hand in a microwave oven.

II. Also, before touching any components or wiring, ALWAYS DISCHARGE THE HIGH-VOLTAGE CAPACITOR FIRST!—see Figures 4-1 and 4-2.

A. The high-voltage capacitor (Fig. 4-1) will quite normally maintain a significant high-voltage charge and, under certain circumstances, an extremely powerful charge, even *after* the oven is unplugged. (The high-voltage components pictured in Fig. 4-1 are described in detail in *Chapter Seven.*) As illustrated in Figure 4-2, use one or, if necessary, two insulated screwdrivers to create a *short circuit* (or direct connection) across the terminals of the capacitor and to chassis ground. Do this by touching the screwdriver blade to one terminal on one side of the capacitor. Then, slide it toward the other terminal (or toward the other screwdriver blade which is already touching the other terminal) until it draws an arc or makes contact. Repeat this procedure to *short* between the capacitor terminals and a bare metal surface of the oven chassis.

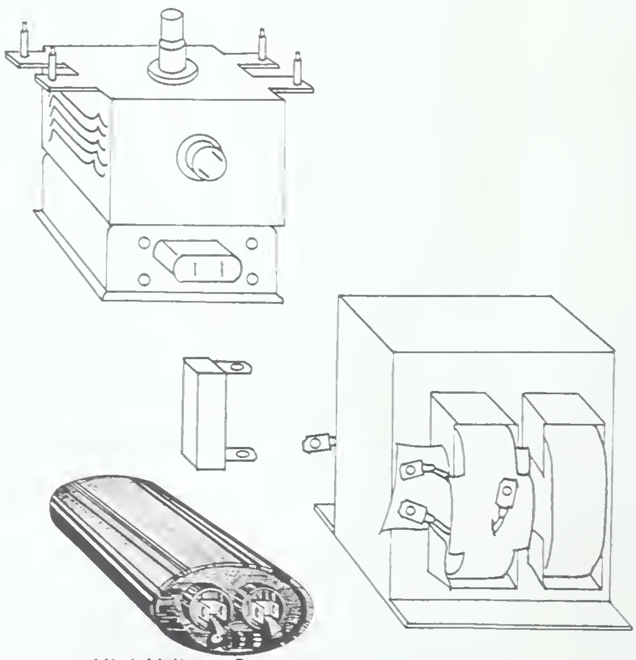


Figure 4-1 Capacitor in a typical high voltage system. (Courtesy of Michael S. Wagner)

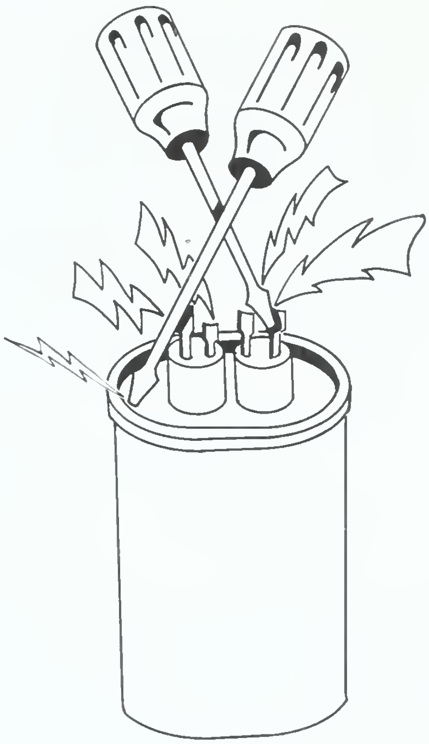


Figure 4-2 Always discharge the high-voltage capacitor first. (Courtesy of Michael S. Wagner)

1. If the capacitor terminals are difficult to reach, there are other less-certain methods. One way is to short-circuit between the magnetron terminals and its chassis (ground). Another is to *short-out* the high-voltage diode in the same way as described for the capacitor. In each of these cases, the successful discharging of the capacitor will depend on the continuity of the high-voltage transformer windings, and associated circuit connections.
   (a). NOTE: On models (such as those manufactured by *Panasonic* and *Litton*) with a VARIABLE POWER RELAY *in* the high-voltage system, the capacitor *must* be discharged at its terminals. This may require that you carefully disconnect wires that lead to the capacitor and short these wires together and to ground.
   (b). On some *older* units (generally those made by *Panasonic*) a dual capacitor arrangement (two capacitors within one case) is used to effect the *cook* and *defrost* modes. When discharging the capacitor on these models, the defrost switch must be in the *off* position to complete the discharge circuit.
   (c). The filter (also referred to as *RF* or *by-pass*) capacitors (see *Sec. 7.3.4*) within the magnetron tube in some ovens manufactured by *Amana* will retain a charge when certain types of failures occur. Grounding the magnetron leads by creating a short between each magnetron terminal and ground with the blade of a screwdriver (with an insulated handle) will discharge the filter capacitors.

B. Some capacitors make use of a *bleeder resistor* (Fig, 4-3). Its purpose is to *bleed* off any charge remaining in the capacitor after the oven is turned off. It may be built in to the capacitor (internal) or located externally, across the terminals of the capacitor. It may also be installed across the diode. But, no matter where it is, *do not trust a bleeder resistor.* It may be open.

C. If you forget to discharge a charged capacitor with your screwdriver, your fingers or hand may ultimately provide the discharge path. You only make this mistake a few times because, while the shock is painful, the real punishment comes as a result of your reflex action and the layers of skin you leave behind on razor-like edges, that are there to help you remember to never again forget to *discharge the capacitor.*

1. The high-voltage capacitor may not be the only capacitor in the unit. While others likely do not contain a *high* voltage charge, it is advisable to discharge all capacitors you encounter.

III. When preparing to make an operational or *live* test, make sure the oven is unplugged and the capacitor discharged, then attach the meter leads to the test points with insulated alligator clips (or clip leads). Be careful to isolate the alligator clips from each other, and from the oven chassis. Then, step back (at least about two feet—in case of excessive microwave leakage), plug in the oven, and perform the test.

A. NEVER touch any oven components or wiring with your hand or even an insulated tool during oven cook operation.

B. **It is neither necessary nor advisable to attempt measurement of the high voltage** in a microwave oven. (See Chapter Seven.)

IV. Units should not be operated if the ground prong of the power cord is disconnected.

Figure 4-3 Bleeder resistor on a high-voltage capacitor.

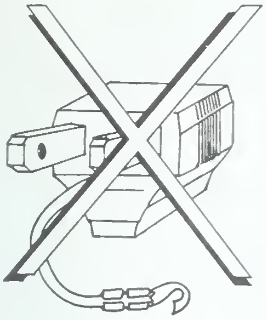


Figure 4-4 Adapter plugs should not be used with microwave ovens. (Courtesy of Michael S. Wagner)

A. For the safety of the customer and the service technician all microwave ovens are designed to operate on a properly *grounded* and *polarized* circuit. Operating a microwave oven with the rounded *ground prong* removed or defeated could result in a serious shock hazard. The use of two-prong adapter plugs (Fig. 4-4) is strongly discouraged by most manufacturers. In fact, in some cases manufacturers will void the warranty until or unless the unit is properly grounded and polarized.

B. Figure 4-5A illustrates how to check a 120 volt outlet for proper grounding and polarization. Notice that the smaller vertical slot should always be *hot* (live) with respect to the larger vertical slot (*neutral*), and the round hole for the grounding circuit. There are several types of plug-in testers (or ground monitors) available which you simply plug in. A correctly or incorrectly wired outlet is indicated by different colored neon lamps.

   1. If the outlet is miswired so that the larger slot is hot with respect to ground, the polarity is *reversed.*
   2. Properly grounded means that the green ground wire in the receptacle is properly connected to earth ground in accordance with current existing electrical codes.

C. Figure 4-5B illustrates proper readings from a 208-240 volt outlet. BE CAREFUL not to touch any metal part of the meter probes.

V. Remove your watch and other jewelry.

   A. These are electrically conductive and serious injury could result if a ring or watch became entangled with a "hot" terminal.

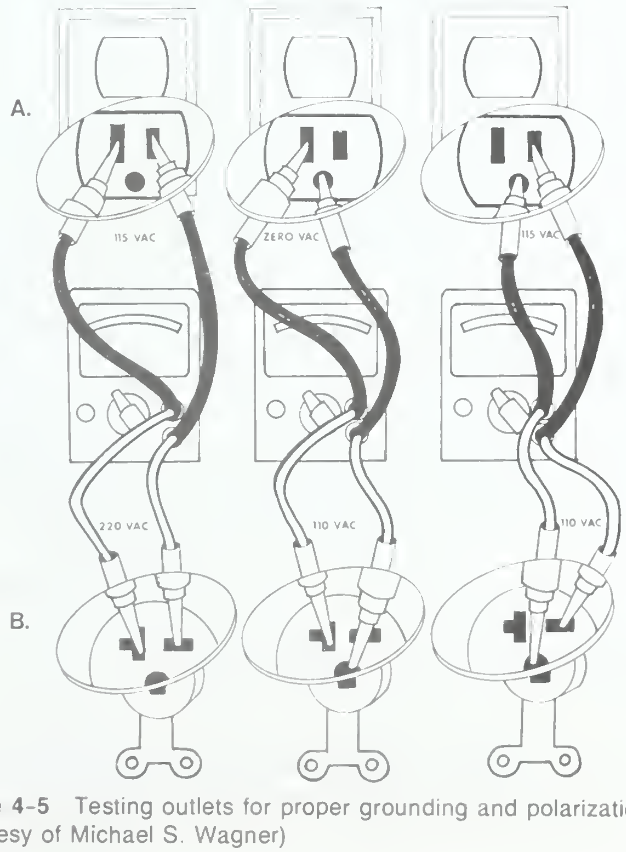


Figure 4-5 Testing outlets for proper grounding and polarization. (Courtesy of Michael S. Wagner)

B. Watches that are susceptible to magnetism will be damaged by the intense magnetic field surrounding the magnetron tube.

VI. Make a habit of using one hand whenever possible. Try putting the other hand in your pocket or behind your back.

A. Two hands could complete a circuit *through* your body. Make it a habit to use one hand, even when the unit is unplugged.

VII. In your *one hand* always use insulated tools.

A. See Section 5.2.1 for a list of appropriate tools.

4.3 WARNING—HIGH VOLTAGE

Just as a deep sea diver must obey certain rules and follow specific procedures to ensure his safety, so too must the microwave oven technician. The high-voltage section (see *Chapter Seven*) of a microwave oven contains more than just high voltage—it also possesses HIGH CURRENT CAPABILITIES THAT COULD BE DEADLY. The difference between a high-voltage, high-current device, such as a microwave oven, and a high-voltage, low-current device, such as a television set, can be seen by comparing the physical size of their respective power cords. The difference is *amperage* (the amount of electric current).

The voltage generating apparatus that is used to electrocute criminals in the electric chair produces about 2000 volts. It is, however, the resulting ***high amperage or high current flow*** that actually inflicts the death penalty on the criminal. The high-voltage circuits in a microwave oven generate from 3000 to 5000 volts DC (direct current). This, coupled with the potential for high current makes the **HIGH-VOLTAGE CIRCUITS OF A MICROWAVE OVEN EXTREMELY DANGEROUS TO WORK ON OR AROUND WHEN THE OVEN IS ENERGIZED.**

Obviously, when it becomes necessary to make certain tests with the power on, extreme caution must be exercised. And, as mentioned earlier, although high-voltage meters for the microwave oven are available, they are not recommended. Most manufacturers flatly state that **measuring the high voltage is neither necessary nor advisable.** I agree with this, because the results derived from checking the high voltage are not conclusive enough to justify the expense of buying the special meter, nor the danger of making the tests. There are other tests (discussed in *Chapter Twelve*) that are equally or more conclusive, and less dangerous.

While the need for extra care around the high-voltage circuits cannot be over-emphasized, it does not mean that one must shrink away in utter terror. There is a difference between a *healthy* fear and an *unhealthy* fear. For example, the deep sea diver mentioned earlier has a healthy fear of the sea that causes him to realize that there are certain things he must do, and those he must avoid doing. Indeed, it is that awareness, and a fear of the consequences of carelessness, that enable him to effectively carry out his assignments, uninhibited by the disabling grip of unhealthy fear. In the same way, it is a ***healthy respect for high voltage*** that allows for effective, yet safe troubleshooting and repair of a microwave oven.

RESPECT HIGH VOLTAGE

4.4 WARNING—POSSIBLE RF EXPOSURE

The personal value of observing certain necessary precautions is dramatically illustrated by one technician's actual experience. The cover had been removed and the microwave oven plugged in. When the unit was put into the *cook* mode to verify a

complaint of "popping and crackling noises", a nearby hi-fi speaker let out a rumble like distorted thunder. The oven was quickly unplugged, and the preliminary visual inspections that *should* have been made before the oven was plugged in, were now being given critical attention. It did not take a magnifying glass to reveal the magnetron tube hanging loose from its mounting in the waveguide. A quick and anxious check with a microwave leakage tester revealed, rather disconcertingly, a "pegged" meter needle—indeed, an egg would have cooked on any nearby surface.

This technician was certainly glad and proud of that hi-fi speaker's warning "groan", in its troubled attempt to reproduce 2450 million cycles-per-second of microwave energy. Since that hair-raising episode, it has become an enthusiastically adopted habit to observe the precautions that follow. It has paid off many times.

In time these checks will become second nature and will take only moments to complete.

I. Make the following safety checks on *all* ovens to be serviced *before* energizing the magnetron or any other operational component, then make repairs as necessary. Many times the problem that brought the unit in for service will become apparent during these preliminary checks.
   A. Verify the operation of the interlock switches.
      1. The most common type of switch used in microwave oven interlock systems is the *snap-action* switch (or *microswitch*). Normally (but not always) an audible *click,* upon lightly pressing its actuator, is an indication of proper operation.
   B. Check the oven door for: (1) proper closing, (2) loose, damaged, or broken hinges, (3) MISSING PIECES, (4) rips, cuts, burns from arcing, or other damage to gaskets and sealing surfaces, and (5) any other visible damage or irregularities.
   C. Inspect the entire unit, especially the door, for evidence of dropping or abuse.

II. *Before* turning on microwave power for any reason, carefully inspect the *magnetron,* the *waveguide* to which it is secured, and the oven *cavity* for proper alignment, integrity, and connections.

III. If there is evidence of tampering or of a previous repair (such as missing screws, or an improperly installed cover) by someone other than one whom you know to be fully qualified—BEWARE!
   A. In this case, double check all of the above. Then look for disconnected, cut, or jumpered wires, especially around the interlock switches.
   B. Make certain that the *fuse* is not defeated in some way.
   C. A brief inspection of the *stirrer compartment* (see *Chapter Eleven*), which contains the not readily visible *stirrer blade* (or *antenna* in some models), might prevent a surprise firework display that could be quite damaging.

IV. Before energizing cook mode, have an approved RF SURVEY METER (see *Sections 5.2.3* and *15.7.1*) **IN HAND** and **READY**. As an added precaution, wear special protective glasses if available. *Section 5.4* describes special glasses that are easily made, and are quite effective.
      1. If the *RF gasket* (which is a concealed wire-knit gasket that seals the union between the magnetron tube and the waveguide—Fig. 4-6) is damaged or missing, it would be visually

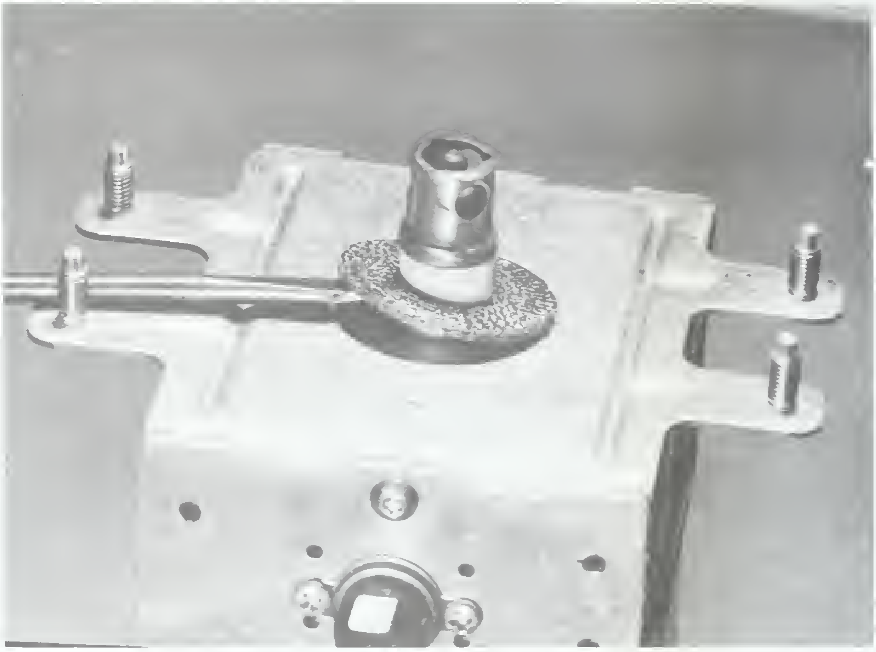


Figure 4-6 RF gasket.

indiscernible and would result in dangerously high levels of RF leakage.

V. After any adjustment or repair on a microwave oven, a final **microwave leakage check** *must* be performed as outlined in *Section 15.7.1.* This is to ensure that the unit does not emit excessive radiation and to verify compliance with current requirements of the Federal Performance Standards for Microwave Ovens as set by the U.S. Department of Health and Human Services (HHS).

1. This test must be performed using only an *industry approved* RF survey meter which, as of this writing, would include the NARDA 8100 and 8200, HOLADAY HI-1500 and HI-1501 or SIMPSON 380M leakage monitor (See *Section 5.2.3*).
2. At least *once a year* have the RF meter checked for calibration by the manufacturer or a designated affiliate.
3. The current federal safety standard for microwave ovens in the United States is 1 mw/cm^2 at a distance of 5 centimeters (or about 2 inches) from the oven surface, *while at the factory.* The allowable limit increases to 5 mw/cm^2 at 5 cm when the oven is sold and goes into use, and remains such throughout the life of the unit.
4. Emission or exposure standards set at the state level may vary.
5. If you should receive substantiated information regarding an injury resulting from excessive radiation from a microwave oven, this should be reported to the manufacturer of that unit.

4.5 ON-THE-JOB SAFETY

It has been a long day and you are feeling its effects—you are mentally and physically exhausted. But, you remember Mr. and Mrs. Irascible, and the promise you made to them that morning: "Yes, I realize that your part has been back-

ordered for two months, but we have it now, and your oven will be fixed today." What should you do? First, remember that even under the best of circumstances, a microwave oven is a dangerous piece of equipment on which to work. Next, add in the effects of fatigue; reduced work efficiency, resulting in sub-standard work, and decreased awareness, which greatly increases the chances of a serious mistake. Then calculate the risk. Ask yourself, "If I make this service call in my present state of weariness, would I be heading for an accident?" A reasonable and safe conclusion would be: The Irascibles will still be there tomorrow, but if I push myself to a point of hazardous fatigue, I may not. So the course of wisdom in this case would be an honest and tactful explanation to Mr. and Mrs. Irascible as to why you must reschedule them for another day. Of course, circumstances vary and some are effected more by fatigue than others, but the point is clear: It is usually not worth the risk to attempt repairs on a microwave oven when you are overly tired. The same is true with being *overly hurried.* The old saying "haste makes waste" takes on a grim new meaning when it comes to microwave ovens.

4.6 LIFT SO AS TO BE ABLE TO LIFT AGAIN

Statistics show that work-related accidents are the most common, and many of these have to do with improper lifting. Here are a few safety rules concerning the safe lifting and carrying of a microwave oven. Don't worry, the chiropractors and orthopedic surgeons will never miss the business.

I. Remember that in most microwave ovens all the weight is either on one side or the other (usually on the right as you face the unit). Try to avoid always using the same arm to lift and carry the heavy side. If, because you are right-handed, you always put the weight on your right, it could eventually cause curvature of the spine.

II. When lifting a microwave oven it is always better to have help, if possible. With some larger units you must have help, unless you are fond of back braces and abdominal trusses.

   A. However, if you must lift alone, and from the floor: 1) Make sure there is an unobstructed path to your destination. 2) Locate the power cord, and secure it. 3) Determine which is the heavy side, then, keeping your feet apart and your back as straight as possible (almost vertical), lower yourself to the oven by bending your knees —*not your back.* 4) The angle at which you approach the unit will depend on the length of your arms and legs. 5) Rock the oven back, or to one side, in order to get a hand under the heavy side. (Watch out for those disciplinary sharp, and sometimes greasy, edges.) 6) Get a firm, well-balanced hold on the opposite (lighter) side. 7) From this point there are at least two methods to complete the lift. One way is to kneel on one knee while raising the heavy side of the oven to a balance point on the other knee, then slowly stand. Another is to simply lift from a semi-squatting position. In both methods, however, you must keep your back as straight as possible, tuck your chin in, and *use your legs to do the lifting.* 8) Reverse this procedure if the oven must be placed back on the floor.

   B. Lifting and carrying an oven in a restaurant can be slippery business. When floors are damp and greasy, *watch your step.* When lifting a grease-slick microwave oven, a cloth towel in each hand can save a lot of grief.

III. Carry the oven with care. Do not drag the power cord behind you; it will invariably anchor itself to something. Because of the awkward shape and uneven distribution of weight, careless twists, turns, and bends will very likely earn you a visit to the chiropractor—or worse.

IV. Do not lift an oven over your head.

V. When lifting a microwave oven in or out of an automobile, several factors are involved: 1) A helping hand here, mostly for balance, is very useful, especially if the unit is in a deep trunk. 2) Try to lift in a way that keeps the strain off of your back. 3) If the oven must be tipped up or over, remove any loose items (shelf, rack) that may be inside. 4) An oven situated on a car seat must be *lifted,* not slid out. If the unit is slid across the seat, either pointed screws that protrude from its underside, or edges that rival an upholsterer's knife, will almost certainly rip your customer's seat. A piece of cardboard placed on the seat first will help to avoid a torn seat, and a chafed customer.

A Well-Organized Shop

chapter 5

5.1. INTRODUCTION

"Have you seen the meter?" "Now where did I put that screwdriver?" "Who scratched the Irascible's trim?" "What happened to the rest of the screws?" Expressions such as these are not indicative of a well-organized shop. Organization means arrangement. The secret of a well-organized shop, then, is to have a place for everything, and to keep everything in its place. This way tools, meters, parts, and so forth, are quickly and easily found when needed. Remember too, that a thing's proper place should also be its logical and practical place. For example, the RF meter, which is needed at least once per every repair, would best not be kept in a bottom drawer at the far end of the shop. Keep often-needed tools, parts, etc., nearby and handy.

Care must be taken when storing, transporting, and working on microwave ovens, to avoid scratching or marring finished surfaces. This requires sturdy, easily-accessible storage shelves of comfortable height, well-suited for easy stowing and removal considering the varied sizes and shapes involved. A carpet, or rubber mat on the floor of the service truck will help to keep units from sliding about, possibly incurring damage when being transported.

The work area should be well lighted. The workbench should allow access to all sides, top and bottom of the unit, and must be strong and stable. Some microwave ovens weigh up to 200 unwieldy pounds, and don't forget those edges that punish the clumsy. When it is necessary (as it often is) to tip a unit up on its side, back, or even upside down, a non-abrasive pad of some sort placed between the benchtop and the oven's finished surface, will prevent the needless expense, the frustration, and un-professionalism of carelessly disfiguring someone's brand new microwave oven.

An efficient well-organized shop will save time, ease frustration, and will promote professionalism, stability, and pride.

5.2 TOOLS AND TEST EQUIPMENT

Microwave ovens, for the most part, are designed and constructed so as to require a minimum of special equipment and tools for servicing. A recent trend toward a smaller, more streamlined appearance has complicated this somewhat, but generally speaking, the required *hand tools* are of a fairly common variety. Most of the *test equipment* is of the type you would find in any electronics repair shop. The tools and test equipment in the following list are arranged, to some extent, in order of necessity, beginning with those that are most essential. It is important to note that, in many cases, the more vital a tool, the more use it will receive. Therefore, high-necessity tools and equipment should be of correspondingly high quality. In the case of some tools, it is even a good idea to have a back-up.

5.2.1 Hand Tools

1. PHILLIPS-HEAD SCREWDRIVER, with point size NUMBER 2, and a 4-inch blade.
   (A) A screwdriver with an industrial quality tip is a good investment. The word *frustration* comes from a word meaning "in vain." To labor with a *tip-worn* Phillips-head screwdriver, is the essence of frustration.
   (B) A magnetic tip is also very helpful.
   (C) This tool is used extensively; it would be wise to have at least two.
   (D) Not used as often, but handy when needed are the point sized NUMBER 01, and especially NUMBER 1 PHILLIPS-HEAD SCREWDRIVERS.
   (E) "STUBBY", and OFFSET SCREWDRIVERS are useful, if not essential, in awkward places.
   (F) An ELECTRIC SCREWDRIVER, while not necessary, certainly is a time-and-wrist-saving convenience.
2. NUTDRIVERS, 1/4 AND 5/16-inch.
   (A) While these two sizes are required repeatedly, an ENTIRE SET of NUTDRIVERS, from 3/16 to 1/2-inch hex size, would be beneficial.
   (B) Metric sizes 5.5, 7 and 8 mm. are required for many brands.
   (C) Magnetic inserts are also helpful.
3. LONG-NOSE PLIERS
   (A) A necessity for reaching into places and performing work difficult for any other tool. These are available with side cutters and a [wire] stripping hole.
   (B) While the standard size is usually sufficient, the NEEDLE-NOSE type may also be required for more intricate work.
   (C) The rounded tip and flat gripping surface of DUCK-BILL PLIERS have also proven very useful.
   (D) The smaller MIDGET SLIM-NOSE pliers are designed for precision subminiature type work.
4. DIAGONAL CUTTING PLIERS
   (A) The standard 6 to 8-inch size will handle a wide variety of cutting jobs. For more intricate snipping applications, such as printed circuit board repair, a smaller 4 to 5-inch size is handy.

5. WIRE STRIPPING AND CRIMPING TOOL
   (A) An all-purpose tool is available that can be used to crimp connections, cut wire, strip wire, and slice bolts.
6. STANDARD TIP (or SLOTTED HEAD) SCREWDRIVER
   (A) These screwdrivers come in a variety of shapes and sizes. The *square shank* type allows for wrench-assisted turning which is very seldom, if ever, called for in microwave oven repair. The rounded shank allows for much greater versatility of use, such as access to recessed holes and other tight or restricted places.
   (B) The MEDIUM SIZE (3/16-inch blade width and approximately 6 inches overall length) slotted or standard tip screwdriver will suit the needs of most applications. However, as with the Phillips, a shorter "STUBBY" SIZE is also most useful.
   (C) "Useful" does not begin to describe the innovative, diverse and problem-solving applications of a small POCKET SCREWDRIVER with a MAGNET in the handle. This little implement, usually only available for purchase through the larger electronics supply companies, is practically indispensable.
   (D) Also, at times indispensable, is a SCREW-HOLDING SCREWDRIVER, which as its name implies, holds the screw for you in order to get it started. Much fumbling for dropped screws in tight places is eliminated with one of these tools.
7. SLIP-JOINT PLIERS, 8-inch
8. STANDARD HEX KEY WRENCH SET (or ALLEN HEAD WRENCHES)
   (A) The most commonly used sizes are: 5/64-inch (*Whirlpool*), 3/32-inch (*Litton*), and 7/64-inch (*Amana*).
   (B) At this time, in the United States, the need for metric sizes in this regard has been minimal. In time, however, this may change.
9. SOCKET WRENCH AND WRENCH SET, 1/4-inch
   (A) The sockets should be 6-point, and range in size from 3/16-inch to 1/2-inch. The set should also include a long and a short extension, as well as a spinner handle.
   (B) A METRIC SOCKET SET must include sizes 8 and 15mm.
10. COMBINATION (OPEN-END/BOX-END) WRENCH SET
   (A) Standard sizes from 1/4-inch to 5/8-inch.
   (B) Metric sizes from 7 to 15mm.
11. COMBINATION IGNITION WRENCH SET—standard and metric
12. SOLDERING EQUIPMENT
   (A) This includes a SOLDERING IRON of 25 to 40 watts, depending on your preference, soldering ability, and applications. A dual-heat (100/140 watt) SOLDERING GUN is good to have on the service truck, because of its ability to heat up instantly.
   (B) A good quality 60/40 (60% tin, 40% lead) rosin core solder helps to make joints quickly with a minimum amount of heat. Do not use Acid core type solders as they are corrosive and can cause damage to leads and terminals.
   (C) A SOLDER REMOVAL TOOL is required for printed circuit board repair.
   (D) CLIP-ON HEAT SINKS must be clipped on to the leads of heat sensitive components before soldering.

13. HEAVY DUTY (long-nosed) RIVETER
14. FILES
    (A) Set should include the following files; FLAT SINGLE CUT, FLAT DOUBLE CUT, HALF-ROUND, ROUND, TRIANGULAR, and an IGNITION FILE.
15. SHARPENED PUTTY KNIFE
    (A) This serves as a handy tool for quickly cutting off pop rivets. Slip the sharpened blade up to either the head or the spread end of the rivet, then by tapping the putty knife with a hammer, the blade simply slices off the end of the rivet. Much easier than drilling, much less risk of surface damage than with a cold chisel.
16. ADJUSTABLE WRENCH
17. LOCKING PLIERS
18. VARIABLE SPEED ELECTRIC DRILL and standard set of HIGH SPEED DRILL BITS

5.2.2 Additional Equipment and Supplies

19. SAFETY GOGGLES
20. Assorted "C" CLAMPS
21. HEMOSTAT; a clamping device for holding and positioning small parts, for use as a heatsink, as well as other handy applications. Also referred to as FORCEP CLAMPS.
22. INSPECTION MIRROR; enables viewing of out-of-the-way spots.
23. HAMMERS with suitable head weights and types.
24. ELECTRICIAN'S KNIFE
25. UTILITY KNIFE and SCRAPER BLADE
    (A) Also a hook-type knife, such as a linoleum knife, is good for cutting out sealed-in shelves.
26. EMERY CLOTH and fine to medium grades of SANDPAPER.—Steel wool is not recommended.
27. HACKSAW
28, HEAVY-DUTY VISE
29. PIN PUNCH and LINE-UP TOOL
30. Good quality vinyl ELECTRICAL TAPE
    (A) Underwriter's Laboratory (UL) approved.
31. FLASHLIGHT
32. TAPE MEASURE
33. Fairly stiff DUST BRUSH
34. TWO-STEP STEP STOOL and HEAVY-DUTY GROUNDED EXTENSION CORD as part of the service truck inventory.

There may be other tools (not listed here) that you will find particularly helpful in your case, and by all means, use whatever it takes to do the job and make the job easier. However, never use a tool beyond its capacity, or in an unsafe manner. Keep them clean and use them only to do the jobs for which they were designed. Whether you choose to carry your tools in a tool pouch, a tool case, a tool box, or a tool bag, take care of your tools and they will take care of you.

5.2.3. Test Equipment

1. Suitable RF SURVEY METER
   A. Several instruments currently meet the requirements for approval by the Department of Health and Human Services (formerly the Department of Health, Education and Welfare) and by the microwave oven industry at large. And, a number of devices do not meet those requirements. A 1984 report (FDA 84-8222) prepared by the Conference of Radiation Control Program Directors (CRCPD) and published by the U.S. Department of Health and Human Services (DHHS) titled "Instrumentation for Nonionizing Radiation Measurement" reports the following concerning inexpensive microwave leakage testing devices: "There are also on the market several inexpensive (less than $50) devices which are supposed to indicate when levels above a threshold are exceeded at 2450MHz. Some of these instruments have been evaluated by the NCDRH (National Center for Devices and Radiological Health) and the conclusion of this study was: Based on the [previously presented] findings, it seems clear that there are serious questions about the ability of each of these instruments to distinguish oven leakage levels which exceed the requirements of the Federal Performance Standard for Microwave Ovens (21 CFR 1030.10) from lower levels which do not."—Courtesy of the CDRH and the CRCPD.

      Microwave oven manufacturers and the DHHS currently approve of the instruments listed below for evaluating microwave oven emissions. For current pricing information (prices are subject to frequent and substantial changes, so the inclusion of a current price list would be pointless), availability, and the nearest distributor, contact the respective manufacturer at the appropriate address as provided. All RF survey meters should be checked for proper calibration by the manufacturer, or a duly designated company. The calibration check should be performed *annually,* or as specified by the manufacturer.

      (1) Holaday Industries: MODEL H1-1800 (Fig. 5-1A), MODEL HI-1500 which is no longer available and is replaced by the popular MODEL HI-1501 (Fig. 5-1B).
         (a) Holaday Industries, Inc., 14825 Martin Drive, Eden Prairie, Minnesota 55344; Telephone: (612) 934-4920, Telex: 29+0922, FAX: 612/934-3604.
      (2) NARDA: MODELS 8100B (includes Model 8110B meter —Fig. 5-2A), and 8201 (includes Model 8211 meter—Fig. 5-2B).
         (a) NARDA Microwave Corporation, 435 Morland Road, Hauppauge, New York 11788; Telephone: (516) 231-1700
      (3) Simpson MODEL 380 (Fig. 5-3).
         (a) Simpson Electric Company, 853 Dundee Ave., Elgin, Illinois 60120; Telephone: (312) 697-2260; Telex: 72-2422. In Canada: Bach-Simpson, Ltd., London, On-

(a)

(b)

Figure 5-1 Holaday Industries microwave survey meters. (Courtesy Holaday Industries, Inc.)

tario. In England: Mack-Simpson (U.K.) Limited, Wadebridge, Cornwall. In India: Rutton-Simpson Private, Ltd., International House, Bombay-Agra Road, Vikhroli, Bombay.

2. Suitable MULTIMETER or VOM (VOLT-OHM-MILLIAMMETER)
   A. The meter must have an *OHMS measurement range* of R X 10,000 or higher, and be powered by at least a nine volt battery, in order to accurately check the front to back resistance of the *high-voltage diode*. The meter should have built-in overload protection, and be capable of measuring to as low as 2.5 Volts AC and DC, and as high as 1000 Volts AC and DC. High-Voltage meters are not necessary or recommended. Some high-impedance vacuum tube voltmeters (VTVM) or solid state (FET) meters may show an acceptable diode as "open" in both directions. A comparison check of a known "good" diode will determine the capacity of a particular meter in this regard. The following instruments, or those equivalent, are more than adequate for the job. Information on current

Figure 5-2A NARDA Model 8100B.

Figure 5-2B NARDA Model 8201. (Courtesy NARDA Microwave Corp.)

pricing and purchase availability may be obtained, either from local electric or electronics distributors, or by contacting the respective manufacturers at the address and telephone numbers provided. Those addresses and telephone numbers which are not listed here,

Figure 5-3 Simpson microwave leakage tester Model 380. (Courtesy Simpson Electric Company.)

are included in the more complete listing of manufacturers, addresses and telephone numbers found in *Appendix V*.

(1) Simpson 260 (Fig. 5-4).

(a) Same as Simpson Electric Company above.

(2) Triplett 630-PLK (Fig. 5-5).

(a) Triplett Corporation, 1 Triplett Drive, Bluffton, Ohio 45817; Telephone 800-328-2677.

Figure 5-4 Simpson Model 260. (Courtesy Simpson Electric Company.)

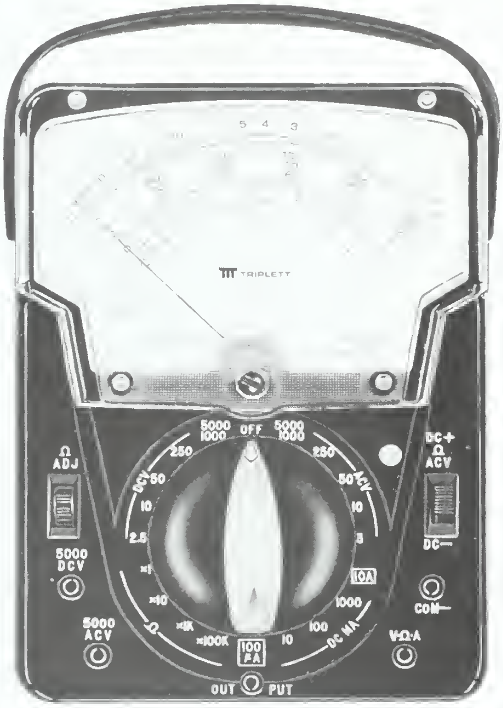


Figure 5-5 Triplett Model 630. (Courtesy Triplett Corp.)

3. TEST BREAKER, and/or POWER TEST BOWL (Fig. 5-6).
   A. Pyrex, plastic or similar non-metallic "microwave safe" measuring container with a capacity of at least 1000 milliliters (1 liter or approximately 4 cups or 32 ounces).
      (1) General Electric part number WB64X73 (beaker).
      (2) Litton part number M95D5, power test kit includes: plastic test bowl and glass centigrade thermometer.
      (3) Robinair part numbers 14881 (600 ml test beaker) and 14882 (1000 ml power test bowl).

Figure 5-6 Power test bowl and beaker.

4. GLASS THERMOMETER
   A. There are several different methods of performing the test which involves the thermometer. These tests are outlined in Section 12.3. The type of thermometer, FAHRENHEIT or CENTIGRADE, will depend on which test you are using. In Fahrenheit, the thermometer scale must range from 0° to 220° F. A centigrade thermometer must have a range from −10° to +110° C (Fig. 5-7).
      (1) Some manufacturers suggest that the red spirit-filled glass thermometer (Centigrade; Robinair part number 14682) is preferable over the mercury filled type (Fahrenheit; Robinair part number 12084). This is because of the possibility of the mercury filled thermometer exploding and shattering, should it accidently be left in the beaker during the test.
      (2) For information regarding the nearest Robinair distributor, in reference to this, as well as other special (Robinair) tools that will be mentioned, contact: ROBINAIR Division—Service Products, Sealed Power Corporation, Robinair Way, Montpelier, Ohio 43543-0193; Telephone: (419) 485-5561.
      (3) Litton centigrade thermometer with −10° to +110° range, part number M95D11.
5. STOPWATCH, or TIMEPIECE capable of accurately timing minutes and seconds.
6. NEON VOLTAGE TESTER.
   A. Twin lead circuit tester indicates the presence of voltage (up to 500 Volts AC or DC) by glowing at an intensity that corresponds to the voltage amplitude.
      A quick and easy way to verify line voltage.
7. THERMOCOUPLE-TYPE HI-TEMPERATURE THERMOMETER; to measure conventional and convection oven temperatures.
8. SNAP-AROUND or CLAMP-ON VOLT AMMETER; not absolutely necessary, but handy on occasion.

Figure 5-7 Centigrade and Fahrenheit thermometers.

5.3 SPECIAL TOOLS

In order to restrict the ability of those other than qualified servicers to tamper with the containment components of a microwave oven, and possibly unwittingly create an RF leakage hazard, certain special tools are required. These are tools that are rarely, if ever, found in the tool box of the home handyman. Some of these may be available locally, and some can be ordered through various microwave oven manufacturers using the part numbers as indicated below. Another, and perhaps more expeditious, means of procurement is to contact the national or international manufacturers of these special tools. Two such manufacturers are: (1) Robinair Manufacturing Company at the address shown above, and (2) VACO Products Company (National), 1510 Skokie Blvd., Northbrook, Illinois 60062; Cable: VACOPRO, TWX 910 686 0658 (International). Information may then be obtained regarding local dealers and distributors.

SPECIAL TOOLS REQUIRED (Company names are followed by their respective part numbers. Refer to illustrations for visual identification.)

1. Number 3 FRICTION HEAD SCREWDRIVER .... Robinair 14474
2. Number 4 FRICTION HEAD SCREWDRIVER (Fig 5-8) .... Robinair 14887
3. Number 5 FRICTION HEAD SCREWDRIVER .... Robinair 14475
4. Number T-10 TORX HEAD (¼-inch bit, Fig. 5-8) .... Robinair 14622
   (Driver) .... VACO 70509
5. Numbers T-15 and T-20 TORX HEAD DRIVERS are more widely available and can be found, either in sets of ¼-inch bits, or individual ¼-inch bits, or as individual drivers, at most local professional tool suppliers. If you have difficulty in locating these sizes, simply contact the aforementioned manufacturers with your need and preference.
6. Number 9 TAMPERPROOF TORX® HEAD DRIVER .... Amana R0193552
7. Number 15 TAMPERPROOF TORX® HEAD DRIVER. (Fig 5-8) .... Amana R0193551
8. TAMPERPROOF SCREWDRIVER (fits most sizes) .... Robinair 14892
9. Number 6 HOLT HEAD SCREWDRIVER (¼-inch bit) .... Robinair 14687
10. Number 8 HOLT HEAD SCREWDRIVER (same, Fig. 5-8) .... Robinair 14543
11. Number 10 HOLT HEAD SCREWDRIVER (¼-inch bit) .... Robinair 14886
12. CROWS FOOT DRIVER (key or bit, Fig. 5-8) .... Litton M95D21
13. "Y"-drive bit .... Amana R0193574
14. A complete set of popular special size bits, including a general purpose screwdriver and three driver handles, is available from Robinair; part

Figure 5-8 Drivers (from left to right): Friction head, torx head, holt head, crows foot, tamper-proof torx head.

number 14877 (Fig. 5-9). This kit would, to some degree, eliminate the need of shopping for some of the tools listed above on an individual basis.

5.4 "HOMEMADE" TOOLS, MISCELLANEOUS EQUIPMENT AND SUPPLIES

There are those *problem-solving* implements, gadgets, and devices that cannot be bought; "homemade" tools, born from a specific shop need, that prove indispensable.

Figure 5-9 Set of popular special bits. (Courtesy Robinair.)

1. POWER INDICATOR LIGHT
   A. When the power indicator light is exposed to microwave energy within the cooking cavity of the oven, it glows with an intensity and variance that is directly proportional to the oven's output power. This light provides a handy means of verifying power, and stirrer operation. A neon power light (microlite) may be purchased (Robinair part number 14848, Fig. 5-10). Or, a microwave indicator light may quite easily be made using a standard plastic encased 117 VAC Neon Indicator Lamp, also referred to as a "Lamp Jewel" (Fig. 5-11—right side), which is obtainable at any electrical or appliance parts supplier. General Electric part numbers: WB2X1608 or WB2X1609. (Note: do not use lamps with metal trimmed casings.)
      (1) Carefully pry off the plastic cover of the indicator lamp. Next, cut the wire leads and the small resistor from the lamp, leaving about 1/4 to 3/8 of an inch of the wire remaining to serve as an antenna. Carefully snap the cover back in place.
      (2) A 6- to 8-inch small fluorescent tube (Fig. 5-11—left side) also serves quite well as a power indicator light. It is recommended that vinyl electrician's tape be wrapped around the metal contacts at each end, forming cone shaped extensions that will serve as metal to metal barriers should the tube happen to roll from its proper centralized position during a test.
2. Special RF SAFETY GLASSES (Fig. 5-12) are made by removing from within a discarded microwave oven door, the perforated metal screen. The screen, which is sandwiched between the inner and outer windows, must be of a fairly pliable nature. Upon gaining access to the screen, cut out a pattern that will conform to, and mold around, the front of a pair of

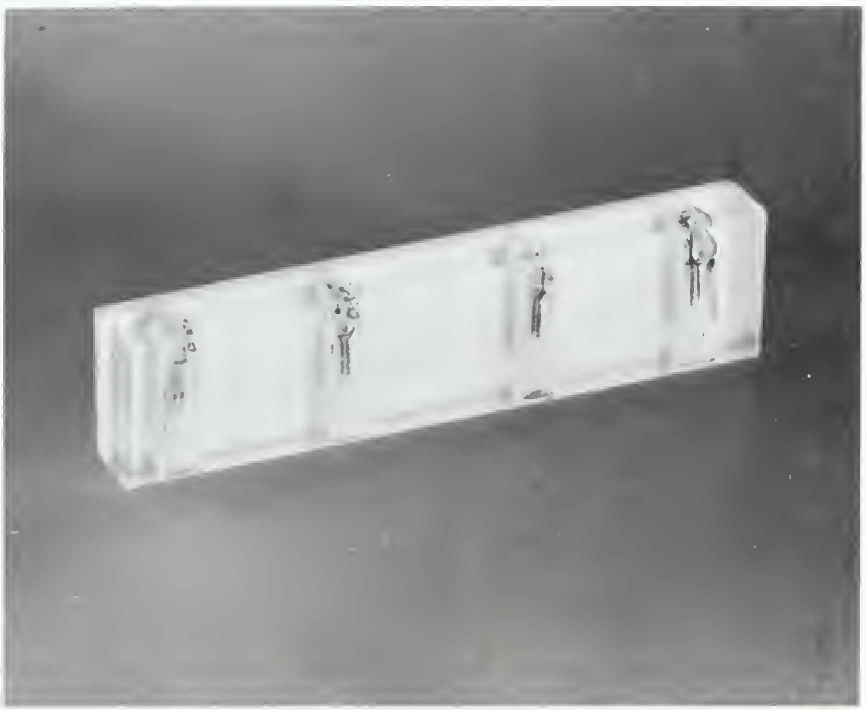


Figure 5-10 Robinair microlite. (Courtesy Robinair.)

Figure 5-11 Power indicator lights.

standard safety glasses or goggles, (sun glasses with the lens removed will also work, but these do not provide the side protection as do safety glasses). Fold the screen around the outer rims of the glasses and secure its edges to each sidepiece with a pop rivet, or with glue.

While these curious looking glasses may give you an alien appearance, they allow adequate vision and provide excellent eye protection in situations where you must determine the source of dangerous levels of

Figure 5-12 RF safety glasses.

stray RF leakage, or, because evidence reveals previous repairs of an obviously unqualified nature you do not know what to expect. In the future you will *clearly see* the value of these "anti-cataract" glasses, there will be many occasions when you will be glad you had them on.

3. A bright FUSE SAVING DEVICE (Fig. 5-13) is made from a 117 VAC outdoor pigtail type lamp socket (found at electrical suppliers and hardware stores). Strip away about 3/4 of an inch of insulation from each end of the two wires which come out of the light socket, and fit the skinned wires with insulated alligator clips. Install a 100 watt bulb in the socket.

   The next time an interlock related fuse blowing problem must be isolated, simply parallel the empty fuse block with the light bulb by connecting one alligator clip to each fuse clip. Then watch with suitable delight as the bulb glows brightly from the current surge that would have wasted another fuse.

   A circuit breaker type device (available from Robinair, part number 14634, Fig. 5-14) temporarily replaces the fuse for testing purposes and, unlike the light bulb device, allows for the increased current flow of the cook cycle. This provides fuse protection when troubleshooting *all* types fuse blowing problems.

4. A CAPACITOR DISCHARGING TOOL (Fig. 5-15) is made from a discarded long-bladed screwdriver with the tip ground down to a point. Strip and attach one end of a two-foot long piece of stranded wire to the upper end of the screwdriver shaft, secure the connection with a small hose clamp. To the other end, connect an alligator clip. Clamp the alligator clip to a bare-metal surface of the oven chassis, and discharge the capacitor by contacting each of its terminals with the pointed end of the shaft.

5. An old flat-tipped screwdriver can be turned into a handy FUSE PULLER by bending the flat blade into a semi-curl shape. Then, with the blade inserted between the fuse and fuse block, carefully pry up one end of the fuse at a time. Obviously, it is preferred to remove a "good" fuse undamaged, but even a "blown" fuse, upon examination, can reveal many clues as to the cause of its failure if removed intact.

Figure 5-13 Fuse-saving device.

Figure 5-14 Temporary circuit breaker. (Courtesy Robinair.)

Figure 5-15 Capacitor discharging tool.

6. A POWER TEST CORD (cheater cord) is made by removing the power cord from a scrapped microwave oven. Then, solder or crimp heavy duty alligator clips to the stripped ends of the black, white, and green wires coming from the molded plug. The alligator clips for the black (hot), and white (neutral) wires should be insulated.

   Among other things, this temporary connecting cord may be used to bypass or isolate individual AC components or circuits in determining their operational status.
7. JUMPER LEADS are made up of various lengths of 18 to 32 gauge stranded wire with insulated alligator clips connected to each end. Alligator clip sizes ranging from "mini" to "heavy duty" with corresponding wire sizes are recommended to meet a wide range of needs (the size of the alligator clips correspond to the wire size, which depends on the intended use).

These clip leads, whether custom made or store bought, facilitate a variety of isolation, temporary elimination, and substitution tests, and are *necessary* for many troubleshooting procedures.

8. An ANTISTATIC WRIST STRAP AND GROUNDING CORD (Fig. 5-16) for avoiding electrostatic discharge problems when handling static sensitive devices can be made as follows: Using a discarded watch (with an electrically conductive band), solder (or otherwise electrically connect) one end of à six foot (length is optional) length of wire to the watchband. Attach the wire to an area of the band where it will cause no discomfort when worn. Then cut the wire somewhere along its length and splice in a one-megohm (one million ohm) resistor in series with the wire. Attach the other end of the wire to ground. Antistatic kits can also be purchased through most electronic wholesalers.

5.5 SUPPLIES

A diversity of CHEMICALS; lubricants, cleaners, adhesives, are useful and will become necessary according to your particular needs and preferences. The following are those which have proven necessary.

A. General purpose LIGHT-DUTY LUBRICANT should be of superior light-grade oil and have the following qualities: metal-protecting and restoring, moisture displacing, cleaning, non-conductive, non-silicone (silicone lubricants or lubricants containing silicone are not recommended because if mixed with oil or grease type lubricants they "freeze" together and become gummy), must be safe on rubber, paint, plastics and fabrics.

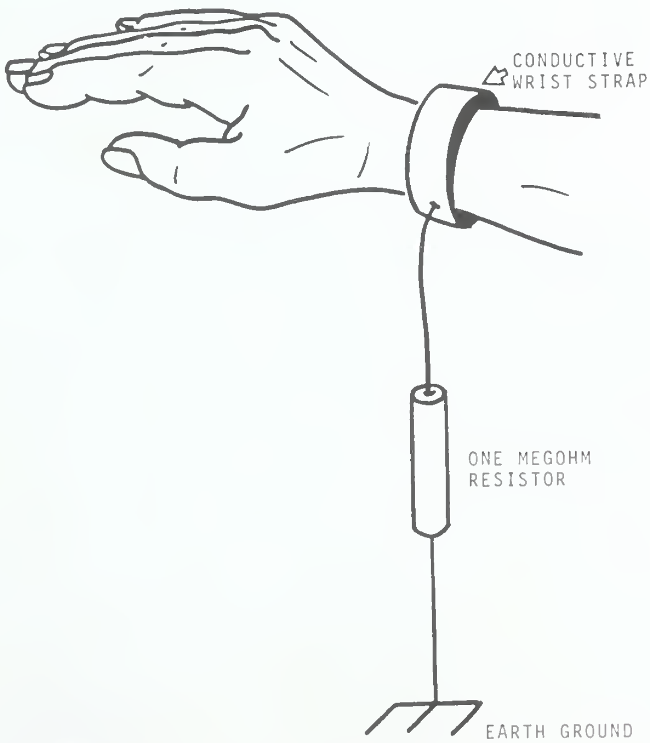


Figure 5-16 Static-control wrist strap. (Courtesy of Michael S. Wagner)

B. Light-bodied GREASE-TYPE LUBRICANT. The same type used to prevent rust and corrosion, and reduce friction loss, in mechanisms with small bearings or gears. (i.e., *Lubriplate*$_R$.)

C. Medium strength THREAD-LOCKING ADHESIVE such as *Perma-lok*^{TM} or *Lock-Tite*^{R}. The adhesive strength must allow for future disassembly in the event that adjustments or replacements become necessary.

D. ADHESIVES for different applications include: epoxy, super glue, radio-TV service cement, and an all purpose contact cement.

Note: Adhesives for special applications, such as RTV shelf sealant that is safe around food products, are best obtained from the appropriate manufacturers or their distributors.

E. For an exact color match, touch-up and spray PAINTS are best obtained from the respective manufacturer. However, in an emergency, off-white (also egg shell or antique white) enamel will come close to the color of most oven cavity interiors. Larger re-painting jobs require sanding, possibly priming, and other preparations.

Where brand names are mentioned, it is purely for descriptive purposes. In most instances, specific brand names are not mentioned or suggested because these various chemicals, sold under a number of different product brand names, are for the most part very similar in quality. It is recommended, however, that the specific characteristics outlined in each case be sought.

The choice of chemical supplies will vary with applications, requirements and preferences. For these reasons, additional compounds not listed here may also be found useful, and should be selected according to individual need and discretion.

Rendering In-home Service with Confidence

chapter 6

6.1 Introduction

Equally important to having the proper equipment is being properly equipped with a professional demeanor and a confident, but not cocky, attitude when providing service in someone's home. This chapter, short in length but long in practical wisdom, offers the advantage of learning from the experience of others. So, notice the importance of the things *not* to do, as well as the things to do.

6.2 Working Under Scrutinizing Eyes

Few things can rival the nerve-racking experience of attempting to repair a microwave oven in a kitchen, on a kitchen counter, all of which belong to, and are cherished by, the very one who is closely watching. Every hint of uncertainty you reveal further heightens the anxiety of an already skeptical householder. Accidentally, the screw driver slips from your hand. As it ricochets off the formica countertop on to the hard-wood floor, the householder winces at the "crack! . . . bang!" Attempting a nonchalant posture, you then crawl under the nearby breakfast table to retrieve it, just as if you expected no less of that "crazy screwdriver." An immutable law of the trades, framed by a presumably hapless person named Murphy, basically states, that, "whatever can go wrong, will." Never underestimate "Murphy's Law."

Although the combined effects of "Murphy's Law" and the misgiving gaze of the householder do present a formidable challenge, it can be successfully met. Just as doctors must learn proper "bedside manner," technicians who must render in-home service must develop a reassuring *"kitchen counter-side"* manner. If you try to discourage the individual (who is standing beside you at the counter) from observing, or you display a lack of poise, it results in him or her either being suspicious of you or feeling sorry for you. In either case this customer's confidence

in you is certainly undermined. While a demeanor of confidence is important, cockiness is out of line. While your self-assuredness instills confidence in the householder, and does much to alleviate their anxiety, being overbearing, obnoxious or insincere is annoying and detrimental. Learn to maintain your poise regardless of what happens. Relax. Politely put the observer out of your mind. He or she will gladly understand when your actions denote an educated and purposeful concentration. Only if your actions indicate a state of helpless dilemma, will the nervous chatter begin. So, develop a plan of action and proceed. Whether or not you immediately "lock on" to the problem is not as important as simply proceeding with *care, deliberation and purpose,* just as if you were in your shop. Every step, regardless of how inconsequential, provides some degree of additional data, and it should *appear* so.

Some other things to consider about making service calls: Your clothing and appearance should bespeak credibility and professionalism. In other words, if, upon your arrival, the householder directs you to the garden tools, you might want to reconsider your choice of attire.

If you smoke, whether it be cigarettes, cigars, pipe, or other, DO NOT smoke in the customer's home. It is extremely offensive to non-smokers; they do not want it in their furniture or their lungs. It is also messy, unprofessional, impolite, and it can cause the customer to suspect that he or she is paying for the apparent *extra time* required by the sheer exercise of smoking in itself.

If you really want some "excitement," just intimate in the slightest way that the householder's microwave oven, a purchase that was carefully thought out and sought out, is somehow *not* the best.

In the course of repair, the unit will be moved to expose the dusty, sometimes dirty and greasy, counter space (or floor, in the case of ranges) beneath it. It behooves the discerning service technician to take a minute and take the opportunity to clean up the not-often accessible area. This includes internal oven components that could be effected by a build-up of grease or dust. Not only is it quite impressive to the appreciative consumer if you generally clean as you go, but you also make a more desirable work area for yourself. Many times *lack* of cleaning *is* the problem itself. Always leave the work area, including the oven itself, as clean or cleaner than you found it.

Consumer knowledge of microwave energy and how it heats is scant and, to a greater or lesser degree, shrouded in myth and mystery. Therefore expect questions, suggestions and suspicions, accordingly. Patiently take time to respond in terms that can be easily understood. Technical double-talk only confuses the customer and heightens his or her skepticism. On the other hand, the time you take to thoughtfully educate the customer will be rewarded with his or her respect for your expertise. This tends to have a satisfying, pleasing effect on the householder who has not only learned something about the operation of the microwave oven, but also about the competence of the servicer.

An all-too-common situation that can test your self-control, is one in which a return call must be made because of a repeat failure. The exasperated customer elaborates, through a forced smile, on the inconveniences this has caused; as though maybe you should pay him or her something. This is a good time to apply some time-tested words of wisdom which state, in essence, that a pleasant response to an angry attack will have a softening effect, like hot coals on an iron-like temperament. Respectfully request that they "hold their fire" until you can determine just what caused the repeat failure. Once determined, a calm and *reasonable* explanation of the problem will usually do much to forge an appreciative apology out of an angry assertion.

While the nature of some repairs do dictate taking the unit to the shop, the

cost-effective course is to strive, if at all possible, to complete the service on location in *one* trip. If, however, for whatever reason, you are unable to complete the repairs on location, avoid that befuddled look, and explain with authority that the unit will have to be taken to the shop.

6.3 Quality of Workmanship

Whether providing in-home or in-shop service, the caliber of your workmanship should be superior. It should make *you* proud. The quality of your workmanship is a direct reflection of the level of your skill and the degree of your qualification. So, good or bad, it is your trademark.

Factory assembly-line people have no special corner on quality, or magical equipment that invokes it. Workmanship standards in the field should be, at the least, those of the factory—and preferably better. Self-respect, customer satisfaction, the esteem of your colleagues, and fewer call-backs, are just a few of the rewards for excellence in workmanship.

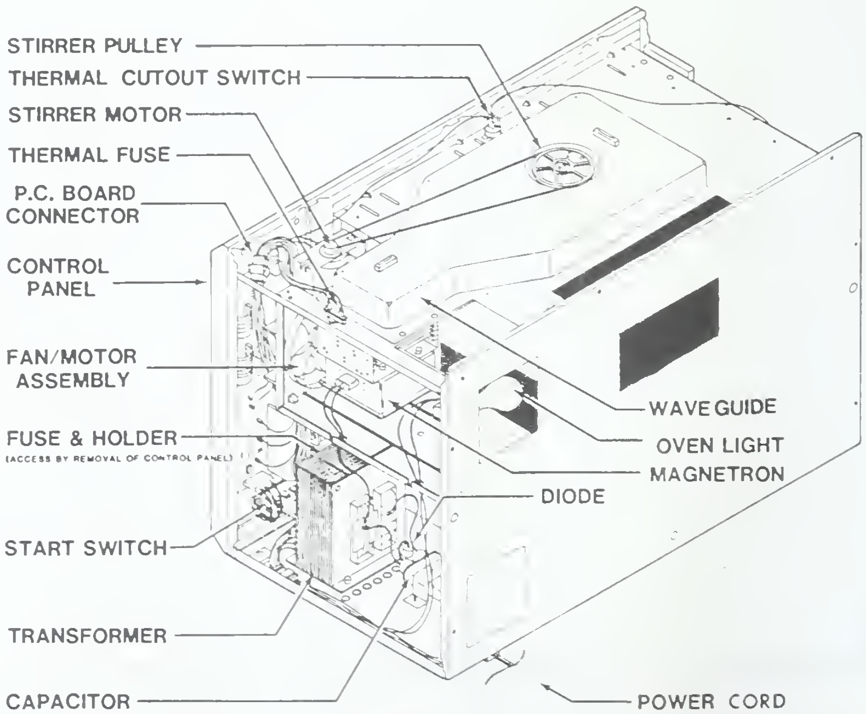
Description of Operation

Part 3

In order to understand how a microwave oven works, it is first necessary to understand *why* it works. This can only be answered by examining the operation and purpose of each of the individual components that combine to produce a working microwave oven.

Part 3, consisting of *Chapters Seven* through *Eleven,* provides a detailed explanation and description of the operation of a microwave oven. This is accomplished by grouping components into respective sections or systems which are designated according to their primary functions, such as the *High–Voltage System* or the *Control Section.* The integral components contained within these sections are then described and their operation is explained. Finally, the sections are connected or combined to develop an overall picture of the entire operating system of microwave oven.

The sections, as they are divided into chapters, are: *Chapter Seven,* the HIGH-VOLTAGE SYSTEM which does the cooking; *Chapter Eight,* the CONTROL SYSTEMS which govern the cooking; *Chapter Nine,* SAFETY AND PROTECTION CIRCUITS, which monitor the system operation, and safeguard the cook; *Chapter Ten,* MICROWAVE CONTAINMENT COMPONENTS, which ensure that only the food cooks; and *Chapter Eleven,* COOLING AND ENERGY DISTRIBUTION SYSTEMS, which prevent overheating, and provide even cooking, respectively.



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The High-Voltage System

chapter 7

7.1 INTRODUCTION

The purpose of the *high-voltage system* (Fig. 7-1) is to generate microwave energy. The heart of the microwave oven, it steps up AC line voltage to *high voltage*, changes the high AC voltage to an even higher DC voltage, and then converts the DC power to RF energy.

The nucleus of the high-voltage system is the MAGNETRON TUBE.

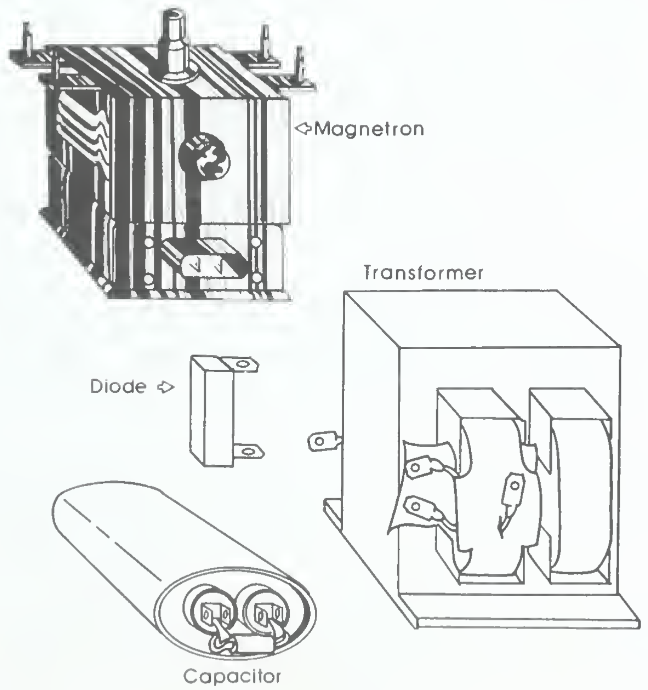


Figure 7-1 Typical high-voltage system. (Courtesy of Michael S. Wagner)

7.2 MAGNETRON TUBE

The magnetron tube is a diode-type electron tube which is used to produce the required 2450 MHz of microwave energy. It is classed as a diode because it has no grid as does an ordinary electron tube. A magnetic field imposed on the space between the *anode* (plate) and the *cathode* serves as the grid. Figure 7-2 is a sectional view of a typical magnetron tube. While the outer configurations of different type magnetrons will vary by make and model, the basic internal structures are the same. These are the *anode,* the *filament/cathode,* the *antenna,* and the *magnets.*

The *ANODE* (or plate) is a hollow cylinder of iron from which an even number of *anode vanes* extend inward, as shown in Figure 7-3. The open trapezoidal shaped areas between each of the vanes are *resonant cavities* which serve as tuned circuits, and determine the output frequency of the tube. The anode operates in such a way that alternate segments must be connected, or strapped, so that each segment is opposite in polarity to the segment on either side. In effect, the cavities are connected in parallel with regard to the output. This will be become easier to understand as the description of operation is considered.

The *FILAMENT* (also called heater), which also serves as the *CATHODE* of the tube, is located in the center of the magnetron and is supported by the large and rigid filament leads which are carefully sealed into the tube and shielded.

The *ANTENNA,* a probe or loop connected to the anode and extending into one of the tuned cavities, is coupled to the waveguide into which it transmits the RF energy.

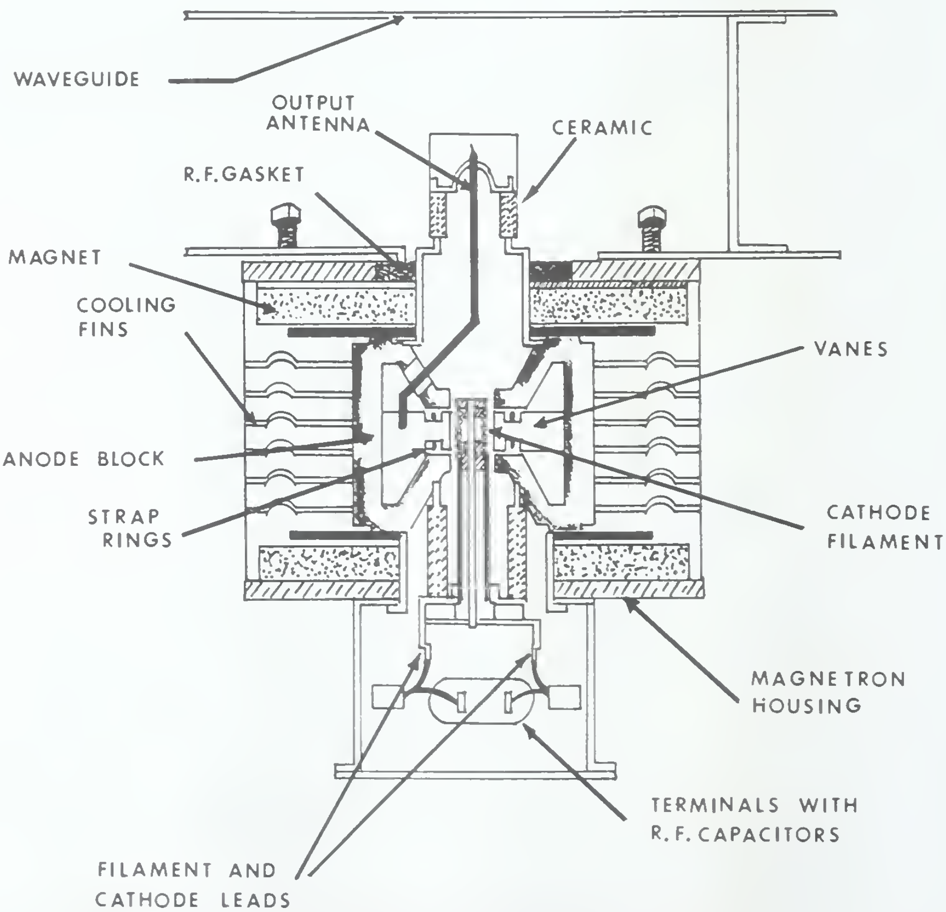


Figure 7-2 Sectional view of a magnetron tube. (Courtesy of Michael S. Wagner)

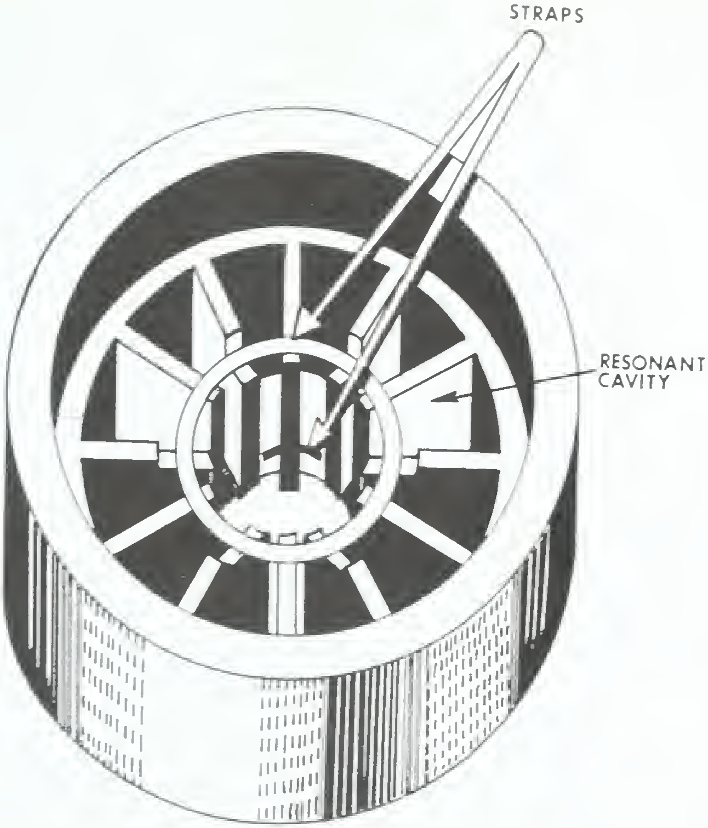


Figure 7-3 Typical anode vane block. (Courtesy of Michael S. Wagner)

The other parts of the magnetron assembly may vary in their relative positions, size and shape, depending on the manufacturer. To keep the following explanation of operation as simple as possible, only the terms that are not self-explanatory as to their purpose will be elaborated on.

The *MAGNETIC FIELD* is provided by strong permanent magnets, which are mounted around the magnetron so that the magnetic field is parallel with the axis of the cathode.

7.3 BASIC MAGNETRON OPERATION

The theory of magnetron operation is based on the motion of electrons under the combined influence of electric and magnetic fields. For the tube to operate, *electrons* must flow from the cathode to the anode. There are two basic laws that govern this motion:

1. The force exerted by an electric field on an electron is proportional to the strength of the field. Electrons tend to move from a point of negative potential toward a positive potential.

Figure 7-4A shows the uniform and direct movement of the electrons in an electric field, from the negative cathode to the positive anode, with no magnetic field present.

2. The force exerted on an electron in a magnetic field is at right angles to both the field itself, and to the path of the electron.

The direction of the force is such that the electron proceeds to the anode in a curve rather than a direct path.

7.3.1 Effect of the Magnetic Field

In Figure 7-4B two permanent magnets are added above and below the tube structure. In Figure 7-4C assume the upper magnet is a north pole and you are viewing from that position. The lower, south pole magnet, is located underneath the Figure so that the magnetic field appears to be going right through the paper. Just as electrons flowing through a solid wire cause a magnetic field to build up around the wire, so an electron moving through space tends to build up a magnetic field around

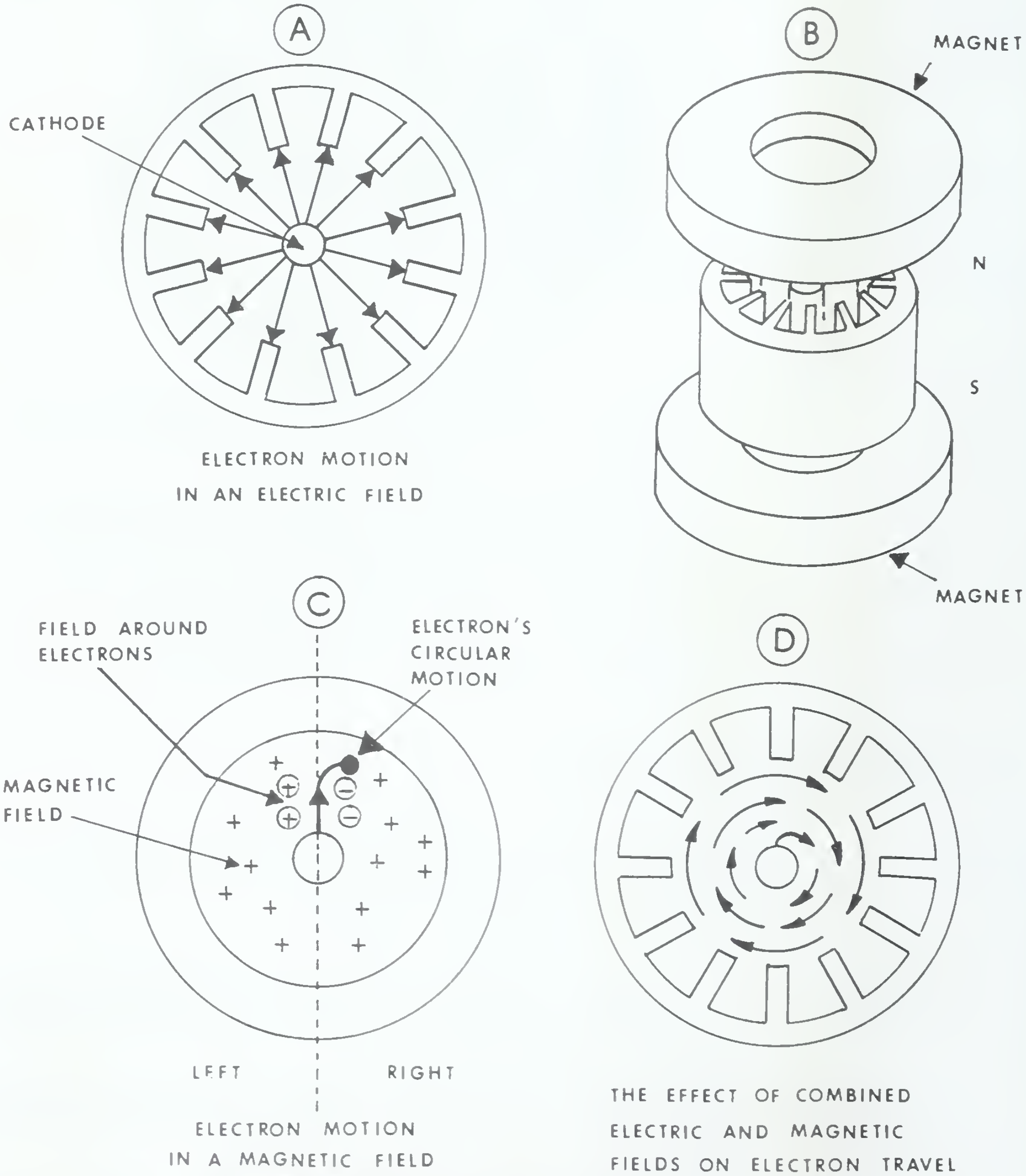


Figure 7-4 Electron motion in a magnetron tube. (Courtesy of Michael S. Wagner)

itself. On one side (left) of the electron's path, this self-induced magnetic field adds to the permanent magnetic field surrounding it. On the other side (right) of its path, it has the opposite effect of *subtracting* from the permanent magnetic field. The magnetic field on the right side is therefore weakened, and the electron's trajectory bends in that direction, resulting in a circular motion of travel to the anode.

The process begins with a low voltage being applied to the filament which causes it to heat up (*filament voltage* is usually 3 to 4 VAC, depending on the make and model). Remember, in a magnetron, the filament is also the cathode. The temperature rise causes increased molecular activity within the cathode to the extent that it begins to "boil" off or emit electrons. Electrons leaving the surface of a heated filament wire might be compared to molecules that leave the surface of boiling water in the form of steam. The electrons, however, do not evaporate. They float just off the surface of the cathode, waiting for some momentum.

Electrons, being negative charges, are strongly repelled by like negative charges. So this floating cloud of electrons would be repelled away from a negatively charged cathode. The distance and velocity of their travel would increase with the intensity of the applied negative charge. Momentum is thus provided by a negative 4000 volts DC, which is produced by means of the high-voltage transformer and the *doubler* action of the diode and capacitor. (4000 VDC is an average, the actual voltage varies with make and model.) A negative 4000 volt potential on the cathode puts a corresponding positive 4000 volt potential on the anode. Needless to say, the electrons leave the vicinity of the cathode with vigor, and accelerate straight toward the positive anode. But not for long . . .

As the electrons hasten toward their objective, they encounter the powerful magnetic field. The effect of the two permanent magnets, positioned so that their magnetic field is applied parallel to the cathode, tends to deflect the speeding electrons away from the anode as described earlier. Figure 7-4D shows the effect of the magnetic field on the path of the electrons; instead of traveling straight to the anode, they curve to a path at almost right angles to their previous direction, resulting in an expanding circular orbit around the cathode that eventually reaches the anode.

The whirling cloud of electrons, influenced by the high voltage and the strong magnetic field, form a rotating pattern that resembles spokes in a spinning wheel (Fig. 7-5). The interaction of this rotating space-charge wheel with the configuration of the surface of the anode produces an alternating current flow in the resonant cavities of the anode. This is explained as follows: as a "spoke" of electrons approaches an anode vane (or the segment between two cavities) it *induces* a positive charge in that segment. As the electrons pass, the positive charge diminishes in the first segment while another positive charge is being induced in the next segment. Current is induced because the physical structure of the anode forms the equivalent of a series of high-Q *resonant inductive-capacitive (LC) circuits.* The effect of the strapping of alternate segments (mentioned earlier) is to connect the LC circuits in parallel (Fig. 7-6).

7.3.2 Resonant Circuits

A resonant circuit consists of a coil and capacitor connected in parallel and produces high-frequency current flow as next explained in Figure 7-7. In step 1 the battery (which represents the energy being supplied to the circuit by the passing "spoke" of electrons) will charge up capacitor C1. In step 2, when S1 is switched to position "B" (which represents the electrons having passed and therefore no longer inducing a charge) the capacitor discharges through coil L1. The current flow through the coil causes a magnetic field to develop around the coil which is accompanied by an internally induced voltage of a polarity that opposes the capacitor discharge. In step

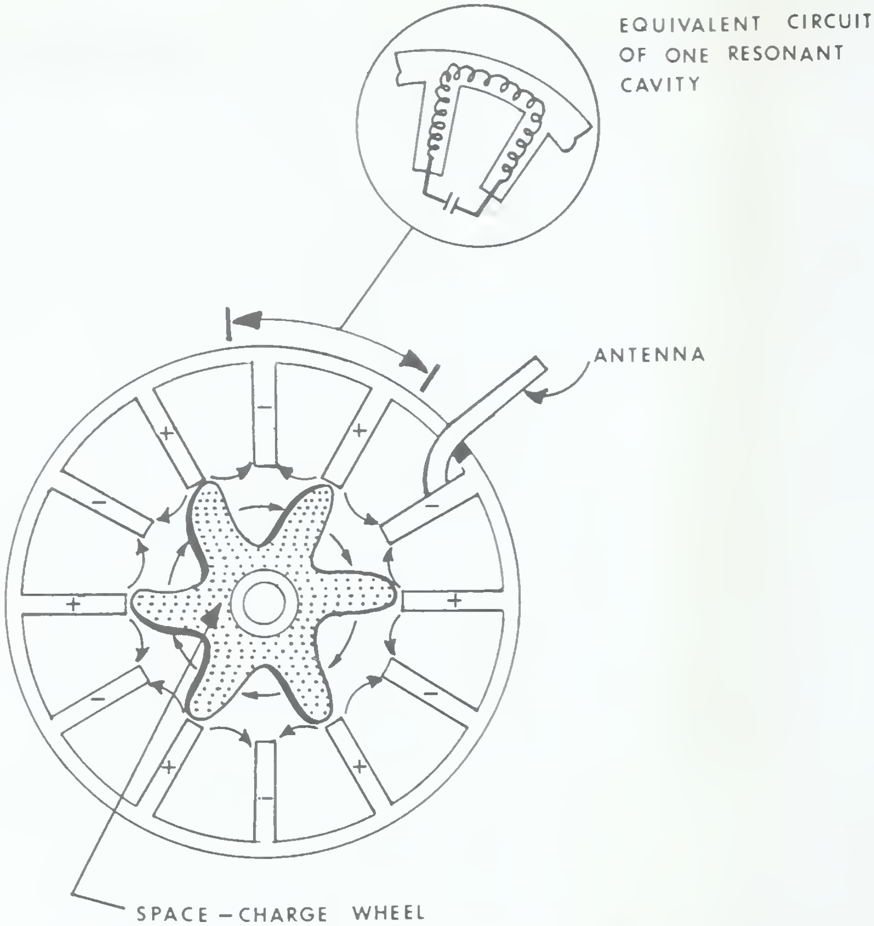


Figure 7-5 Electrons form a rotating pattern. (Courtesy of Michael S. Wagner)

3, C1 has completely discharged and the energy is now stored in the magnetic field that surrounds the coil. In step 4, the magnetic field begins to collapse around the coil causing the voltage induced within it to change polarity. This tends to keep the current flowing in the original direction, which at step 5, charges the capacitor with a polarity opposite from its original charge. Consequently, at step 6 the capacitor

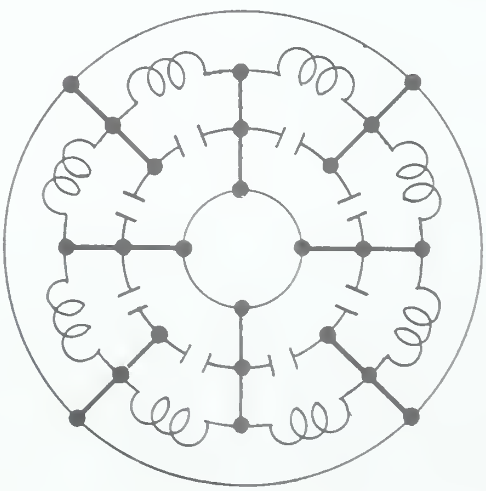


Figure 7-6 Equivalent circuit of cavities in parallel because of strapping. (Courtesy of Michael S. Wagner)

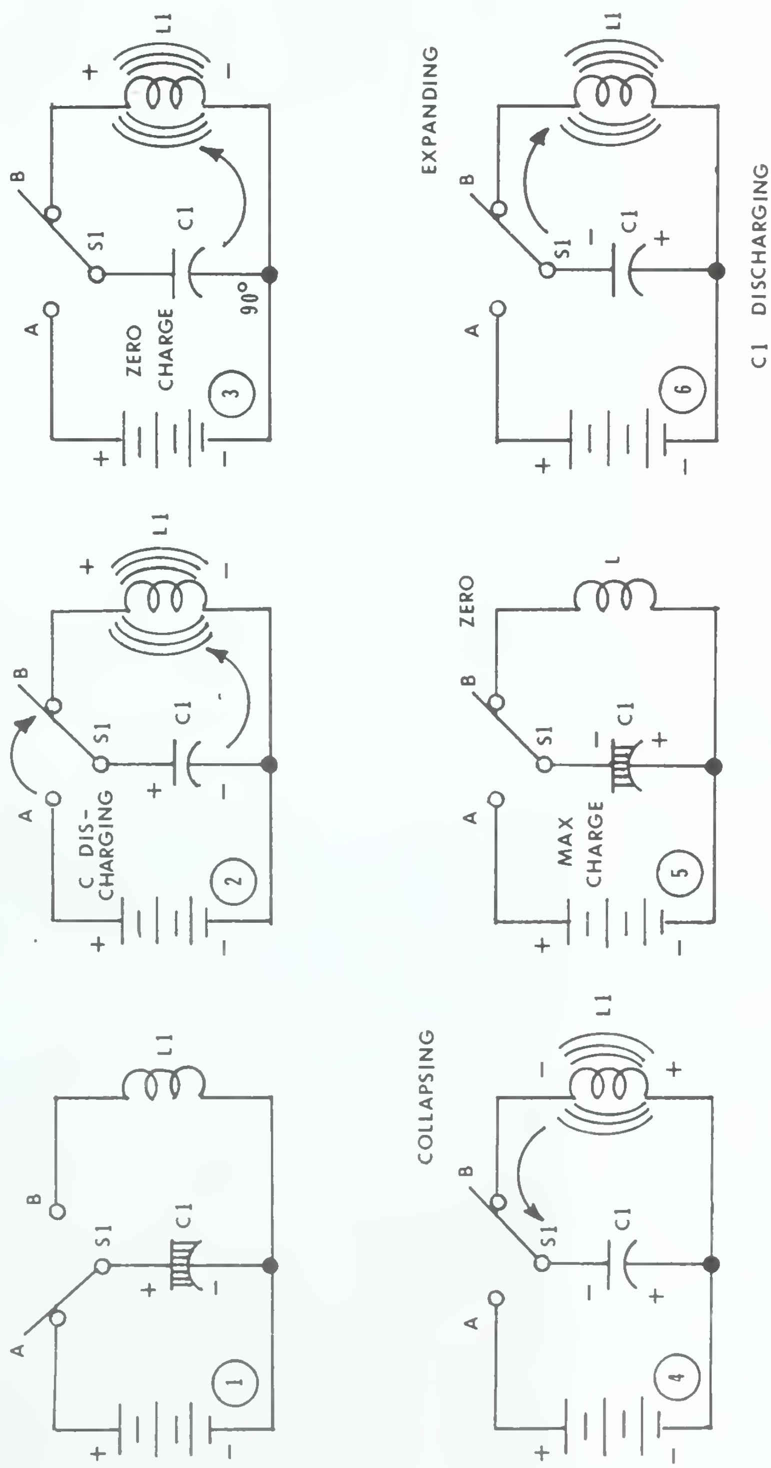


Figure 7-7 Basic operation of a resonant circuit. (Courtesy of Michael S. Wagner)

again discharges through the coil, although in an opposite direction, starting the process all over. This seesaw action can produce extremely high oscillations, the frequencies of which are determined by the values of the capacitance and the inductance.

In each resonant cavity of a magnetron tube, the walls act as an inductor (or a coil), and the parallel sides of the opening form the plates of a capacitor (refer back to Fig. 7-5). Since the amount of inductance and capacitance is very small, the frequency of the alternating current is very high. The electromagnetic oscillations produced in the resonant cavities are intercepted by the antenna which then couples the energy into a waveguide.

7.3.3 The Waveguide

Microwave energy cannot travel through a solid conductor, so the antenna radiates the RF power into a *waveguide*. The waveguide, a hollow metal tube (Fig. 7-8), transports the microwave energy into the oven cavity. Most microwave ovens use a rectangular shaped waveguide, through which the waves of energy travel by reflecting from side to side in a zigzag pattern.

7.3.4 RF Capacitors

In order to prevent small amounts of RF current from backfeeding down the magnetron tube filament leads, which would cause excessive radio and television interference, *by-pass* (or RF) *capacitors* and *ferrite rings* are added to the magnetron assembly (Fig. 7-9). By-pass capacitors filter off any backfeeding current to ground. The ferrite rings are magnetic and oppose high-frequency current flow.

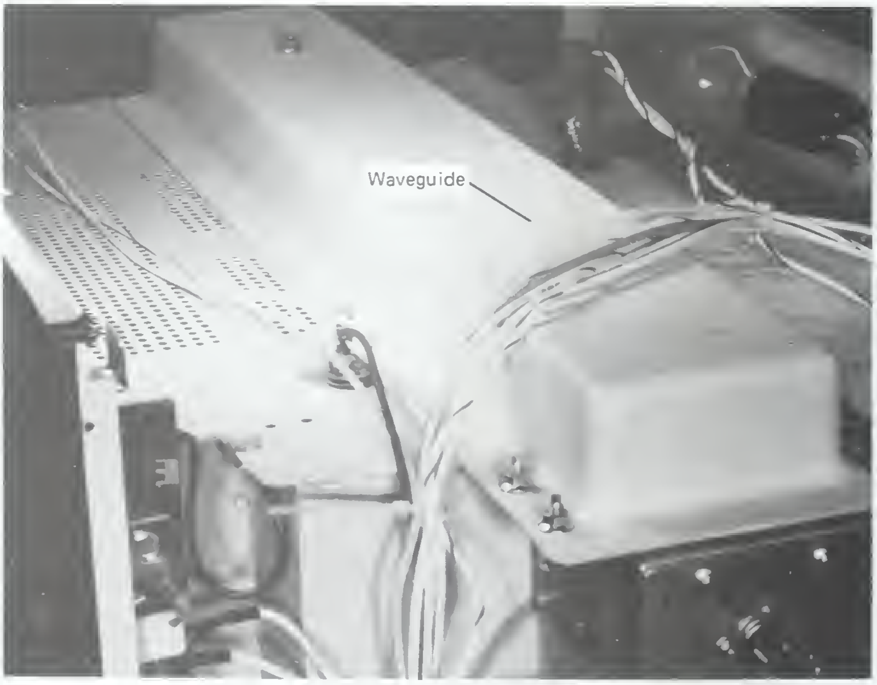


Figure 7-8 The waveguide is a hollow rectangular tube.

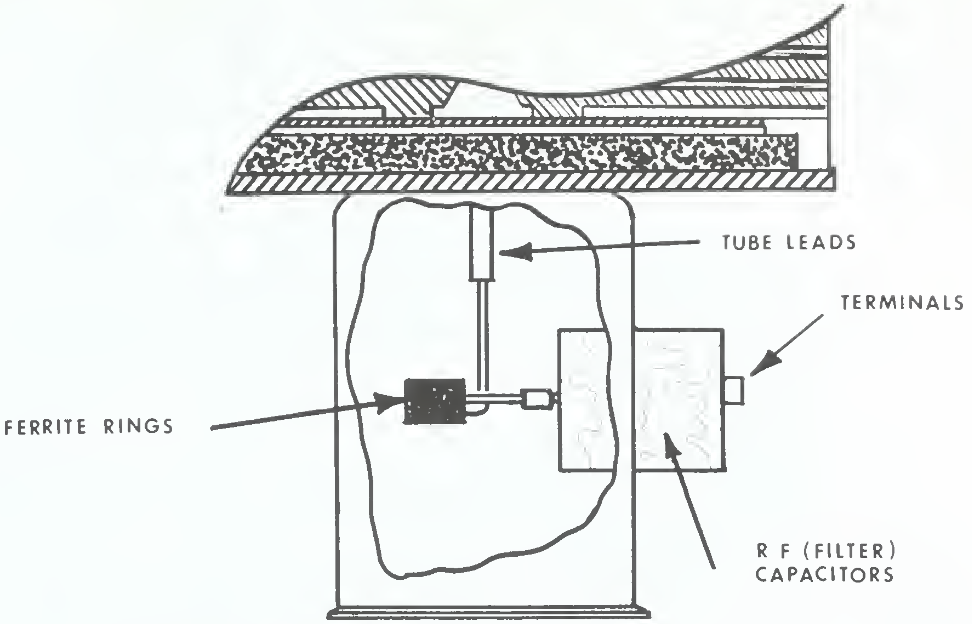


Figure 7-9 RF capacitors and ferrite rings in a magnetron tube. (Courtesy of Michael S. Wagner)

7.3.5 Cooling Fins

Other features of the magnetron structure are the cooling fins which dissipate the tremendous heat generated by an oscillating magnetron, usually maintaining an operating temperature of about a 260° F (86°C).

7.3.6 Proper Phasing

Located near the filament terminals are the designations "F" and "FA" (Fig. 7-10); these insure that proper phasing is maintained when reconnecting the filament and high-voltage leads. Proper phase relationships, or polarities, within the high-voltage circuits are important. Failure to observe these relationships when reconnecting wires can put high-voltage components out of phase with each other. This can cause such symptoms as intermittent "popping," and even the premature failure of the components.

7.3.7 Magnetron Life Expectancy

The typical life of a magnetron tube is approximately 2000 hours of operation. Some factors that can diminish the life of a magnetron are: 1) no-load operation, 2) operating with too much metal in the cooking cavity, 3) line voltage consistently too low or too high, 4) improper phasing, 5) improper installation or removal, 6) replacing associated high-voltage components with substitutes that are incompatible with the system design, 6) continual operation at the upper limit of its heat tolerance due to inadequate air circulation, 7) obstruction in the waveguide, 8) failed stirrer operation.

Coverage of magnetron failure modes, testing, and replacement procedures begins in *Section 12.4*.

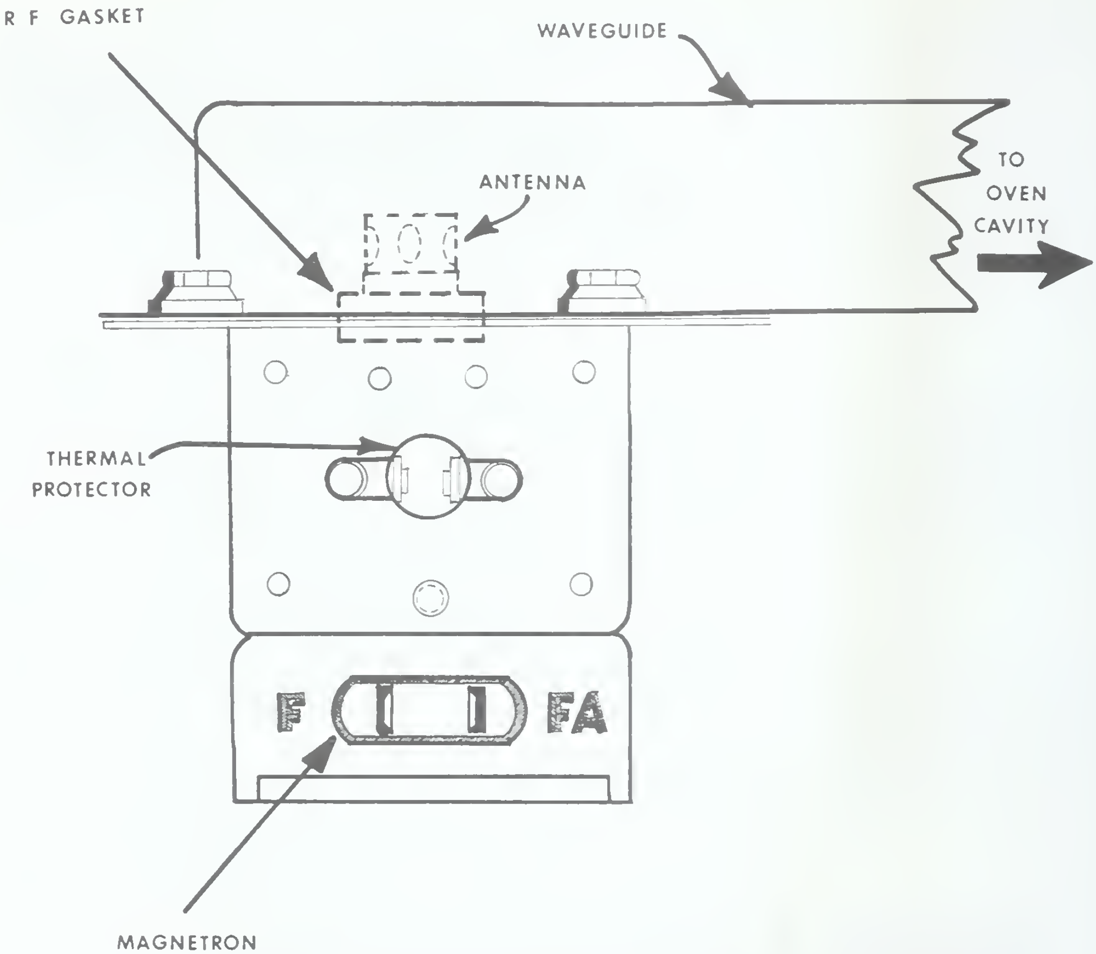


Figure 7-10 Magnetron terminal designations for proper phasing. (Courtesy of Michael S. Wagner)

7.4 TRANSFORMERS

In microwave oven circuits, transformers serve two functions: either they increase (step up) voltage, or they decrease (step down) voltage. The first type of transformer to be considered will be the *step-up* transformer.

7.4.1 High-Voltage Transformer—Fig. 7-11

The *high-voltage* transformer (also referred to as *power* or *plate* transformer) is of the step-up variety. With a typical voltage of 120 VAC (± 10%) applied to the *primary* winding (some commercial units are designed to operate with a primary voltage of 208 to 240 VAC), the transformer will step the voltage up to approximately 2400 VAC at the *secondary* output. Transformers work on a principle called *mutual induction*. It is the physical characteristics of the transformer, combined with an input of alternating current, that produces this process.

A simple step-up transformer consists of an open square or frame of iron called the *core*. Coils of insulated wire are wound around the two opposite sides of the core forming two separate coils (Fig. 7-12). As illustrated in Figure 7-12, when alternating current is applied to the *primary winding*, the changing current flow produces a magnetic field within the iron core that reverses with each alternation of

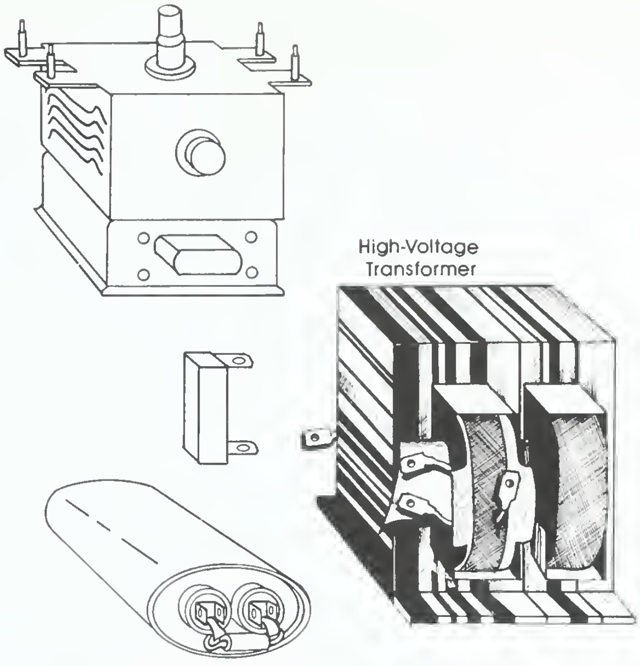


Figure 7-11 High-voltage transformer in a typical high-voltage system. (Courtesy of Michael S. Wagner)

the applied current. Since a conductor moving through magnetic lines of force will have a voltage generated within it, it follows that a stationary conductor placed within a changing magnetic field would also have a voltage generated or induced within it. Such is the case with the *secondary winding.* If the two ends of the secondary winding are connected together, an induced alternating current will flow. While the frequency of the current flow in the secondary is the same as that of the primary, the strength of the induced voltage depends on the ratio of the number of turns in the secondary winding to the number of turns in the primary winding. For

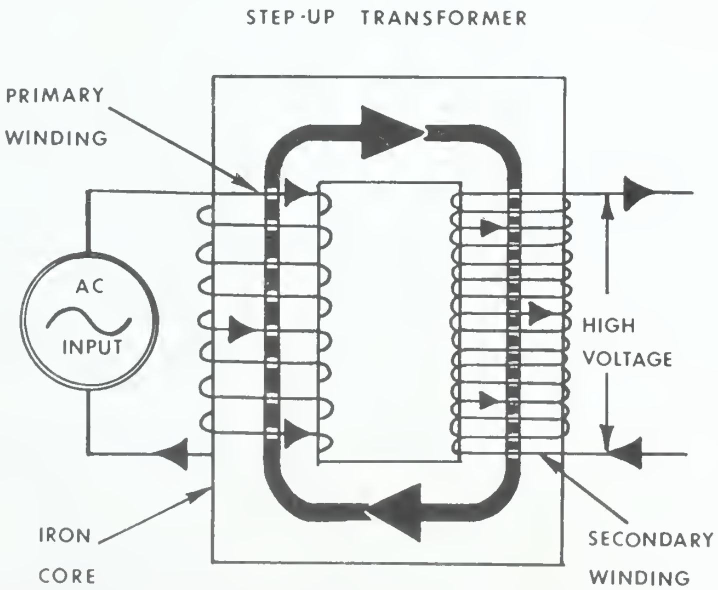


Figure 7-12 Simple step-up transformer. (Courtesy of Michael S. Wagner)

example, a primary of 8 turns and a secondary of 16 turns would be a ratio of 1 to 2. At that ratio, 120 VAC applied to the primary would produce 240 VAC at the secondary.

Transformer design and construction depend on the way in which it will be used. Microwave ovens use a *saturated core* type, in which the core operates at magnetic saturation. Thus, any variation in the primary, such as a voltage drop or surge will not affect the constant output of the secondary.

Whereas all high-voltage transformers used in microwave ovens have at least one *secondary terminal* (or *high-voltage tap*), some have two or more high-voltage outputs (Fig. 7-13). The high-voltage terminal labeled "HI" utilizes the full number of turns in the secondary coil and thus yields the maximum high-voltage output. By tapping into the coil at a point having less turns, the terminal designated as "LO" utilizes only part of the secondary winding. Thus, output at the "LO" tap is correspondingly less than that of the "HI" tap. While these additional taps are provided to compensate for variations in capacitor values, they afford other benefits also: The weakening RF output of an aging magnetron tube can be boosted by changing the high-voltage output from the "LO" to the "HI" tap. A different tap selection can also improve an unsatisfactory RF-energy cooking pattern.

Additional primary and secondary terminals are also provided on the transformers in certain models that enable conversion of the power supply operating frequency. These models can be converted to operate on either 60 Hz or 50 Hz. The pertinent conversion instructions are usually affixed to the inside of the outer cover or side panel. See *Section 12.9.1* for an example of a common method of frequency conversion which involves the high-voltage capacitor.

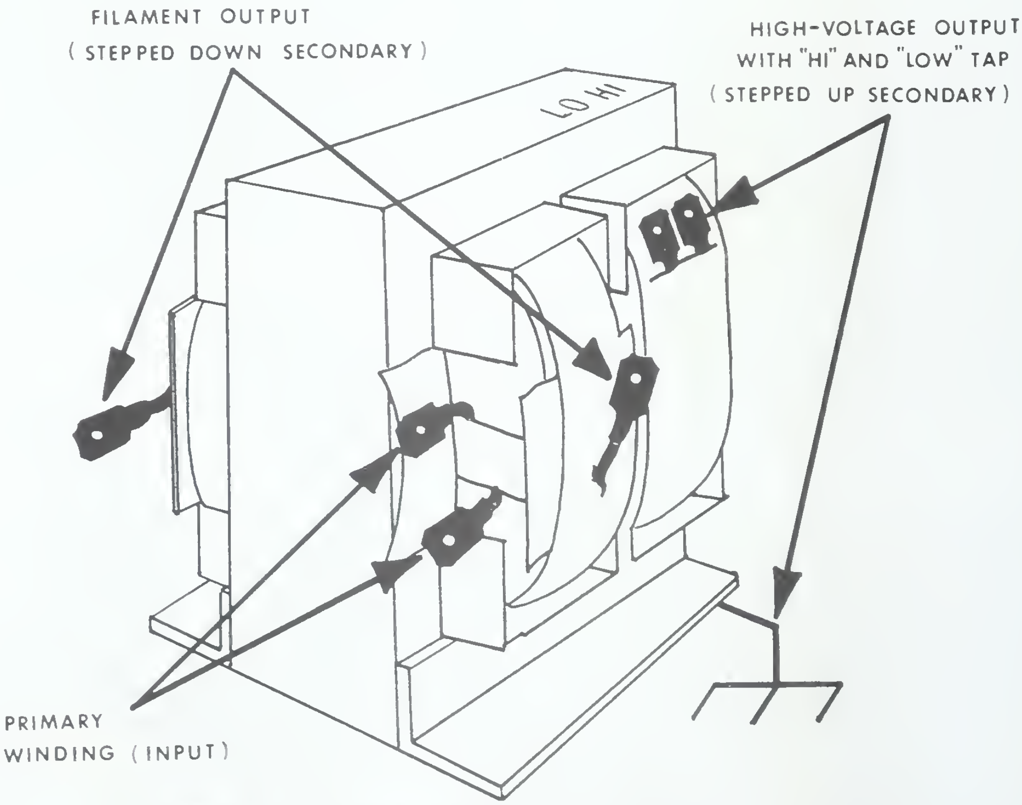


Figure 7-13 Typical high-voltage (power) transformer. (Courtesy of Michael S. Wagner)

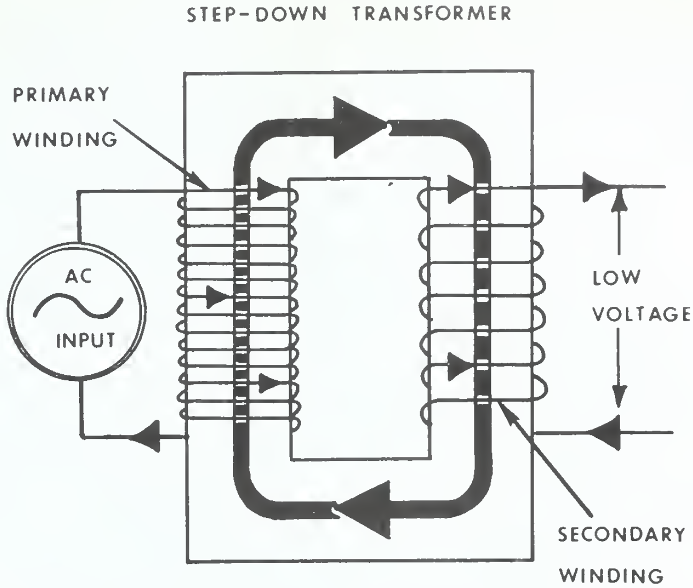


Figure 7-14 Simple step-down transformer. (Courtesy of Michael S. Wagner)

7.4.2 Filament Transformer

Secondly, the filament transformer is of the step *down* variety (Fig. 7-14). A voltage of 120 volts applied to the primary winding of the filament transformer is *stepped down* to approximately 3 VAC (the actual filament voltage varies with different models). This low-voltage, *high-current* output of the filament transformer is used to heat the magnetron filament. In an increasing number of microwave ovens the step-down windings of the filament transformer are incorporated within the structure of the high-voltage transformer, as in Figure 7-13. This means that from a common primary, voltage is stepped up in one secondary winding, and stepped down in the other. In other cases the filament transformer is a separate, smaller unit. (Figure 7-15 shows a typical filament transformer.)

Even smaller, in size and output, are the low-voltage (or control) transformers (Fig. 7-16). These usually have several secondary taps which provide an appropriate selection of control voltages as required by the various electronic control panels. These control transformers are not part of the high-voltage section, rather they are a component of the control section and thus covered in greater detail in *Section 8.8*.

The transformers discussed here are common to all microwave ovens, with the exception of the low-voltage transformer which is not required in models that use mechanical timers and controllers. Other types of transformers, their applications and functions, will be explained as the need arises.

Transformer testing procedures and failure modes, with related symptoms, are outlined in *Section 12.8*.

7.5 THE HIGH-VOLTAGE CAPACITOR AND DIODE—THE VOLTAGE-DOUBLER CIRCUIT

In most domestic models of microwave ovens, the high voltage necessary to operate the magnetron is generated by the action of a *diode* and *capacitor* (Fig. 7-17) combination that effectively doubles the voltage, and is aptly called a *voltage doubler*. A step-up transformer alone could produce the required high voltage, but it

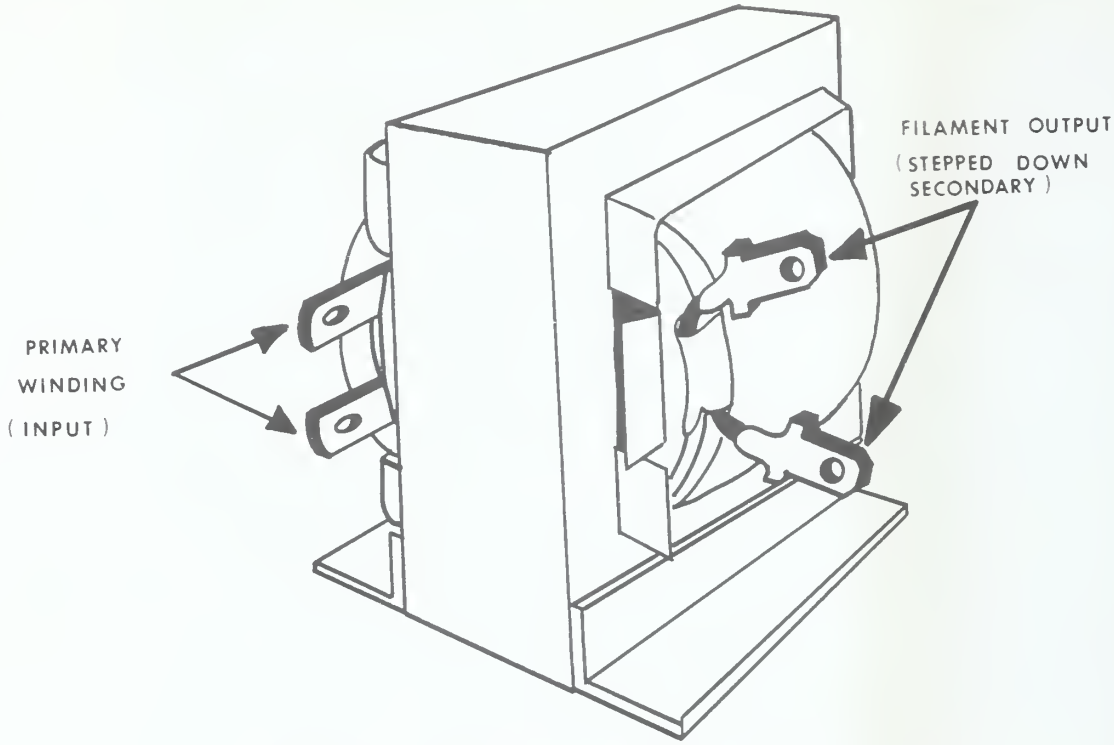


Figure 7-15 Typical filament transformer. (Courtesy of Michael S. Wagner)

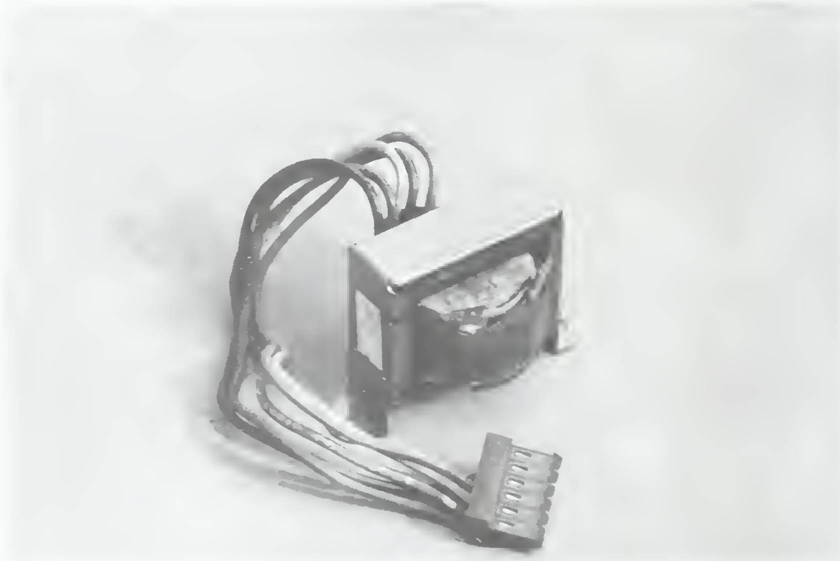


Figure 7-16 Typical low-voltage transformer.

would be immense in size, weight, and expense. The doubler circuit allows for the use of a much smaller high-voltage transformer by *doubling* the transformer's already-stepped-up output voltage. Thus, the required high voltage is obtained from smaller, lighter, and less expensive components. While most models today use a *half-wave* doubler circuit, many commercial models still in the field use a *full-wave* voltage doubler circuit. Important to the understanding of a voltage doubler circuit is a basic knowledge of its two components, the capacitor and the diode.

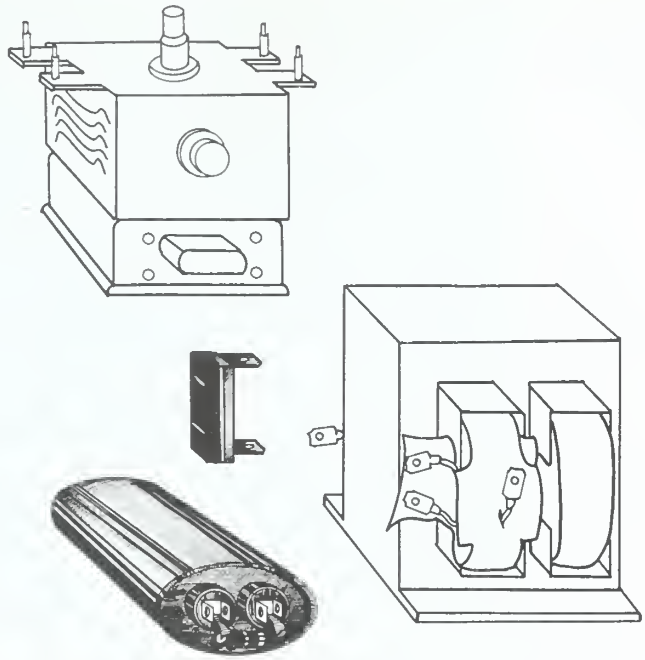


Figure 7-17 The capacitor and diode form a voltage doubler. (Courtesy of Michael S. Wagner)

7.5.1 The High-Voltage Capacitor

Essentially, a capacitor is made up of two metal plates separated by an insulator or *dielectric*. Oil usually serves as the dielectric in microwave oven capacitors. Capacity means a maximum *ability to hold or contain*, so a capacitor may be thought of as a device that temporarily stores electrons. This energy is stored in the form of a *charge*. The amount of capacitance depends on the surface area of the metal plates, the distance between the plates, and the type of dielectric material. Capacitance is measured in *farads*. However, a capacitor with a value of 1 farad would be of enormous dimensions, so practical units of capacitance are more commonly referred to as *microfarads*. Figure 7-18 shows an array of capacitors that are typically used in

Figure 7-18 Typical high-voltage capacitors.

the voltage doubler circuits of microwave ovens. This application calls for capacitance values ranging from 0.7 to 1.5 *microfarads,* depending on the make and model.

Just as when blowing up a balloon the air does not pass through the balloon, but is *stored inside* until released, so too with electrons flowing into a capacitor; they do not flow through the capacitor, but rather into and out of it at the frequency of the applied voltage. Figure 7-19 depicts a capacitor in its simplest form. If a voltage is applied as shown in part (A), electrons will flow onto plate "X" making it negative. Electrons cannot flow through the dielectric material between the plates, so plate "Y" becomes positive with respect to plate "X." If the voltage source is now removed, as shown in part (B), the capacitor becomes a source of potential energy, similar to a charged battery. By allowing the capacitor to discharge through an external circuit, as shown in part (C), the stored energy may be utilized and the potential difference between the two plates becomes zero. If the polarity of the voltage source is reversed, then re-connected, the same sequence of action would occur except that corresponding polarities would be reversed.

Unless high-voltage capacitors are provided with a discharge path, they will retain a significant charge even after the unit is shut down and unplugged. For that reason many manufacturers add a bleeder resistor, either externally (Fig. 7-20) or

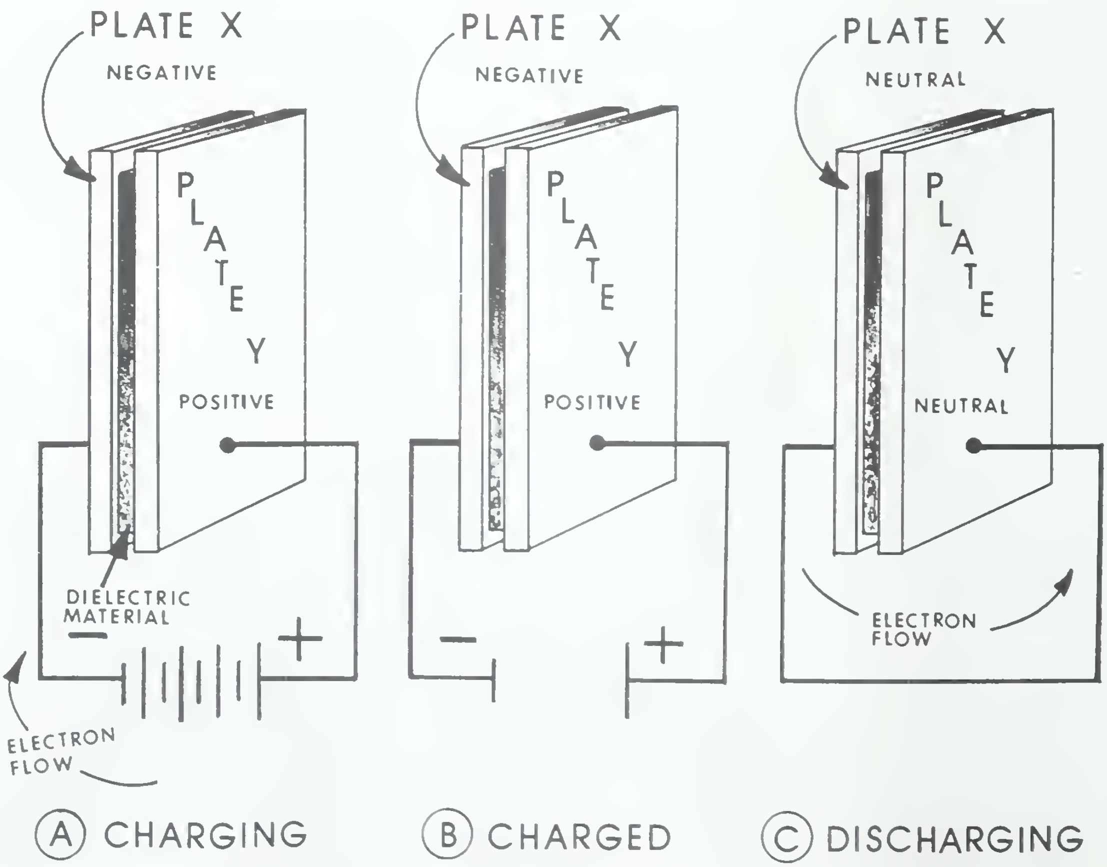


Figure 7-19 A simple capacitor. (Courtesy of Michael S. Wagner)

Figure 7-20 Capacitor with external bleeder resistor.

internally. The sole purpose of this very high-ohm resistor is to protect servicing personnel by allowing any high electrical charge that may be present to dissipate or bleed off within 20 to 30 seconds after the oven is shut down. Whether or not you trust the bleeder resistor is up to you. However, if it is open, and if your finger provides the discharge path, your reflex action could make you the bleeder.

A *blower capacitor* is found in some commercial microwave ovens (i.e., *Litton).* This comparatively smaller capacitor is connected across the start and run windings of the motor, and provides a constant phase shift that ensures maximum speed with minimum current draw.

Also employed by some commercial units is a *filament capacitor.* This capacitor provides a degree of voltage stabilization for the filament transformer to ensure a constant secondary voltage in the event that variations or fluctuations of the source voltage should occur.

Many capacitors are manufactured with a $\pm$ 10% (approximate) tolerance in capacitance. These capacitors are color coded with a paint dot to indicate their actual value. A capacitor rated at 1.0 Mfd with a white or black dot would actually be slightly lower than the rated 1.0 Mfd. Correspondingly, a red or yellow dot would indicate a slightly higher value.

In some cases there are variations from the above characteristics, as well as in the specific application. One such variant is the dual-rated capacitor used to facilitate the conversion of the power supply operating frequency. This feature allows models so equipped to be operated at 50 Hz or 60 Hz, depending on the line voltage frequency of the country in which it is to be used. See *Section 12.9.1* for a typical frequency conversion procedure.

The question of capacitor interchangeability depends mainly on the value (in microfarads) and the voltage rating. The physical size may also be a limiting factor. And, of course, a capacitor with an *internal* diode cannot be substituted for a capacitor designed for use with an *external* diode, and vice versa.

Various types of failures, associated symptoms, and testing procedures for the high-voltage capacitor are covered in *Section 12.9.*

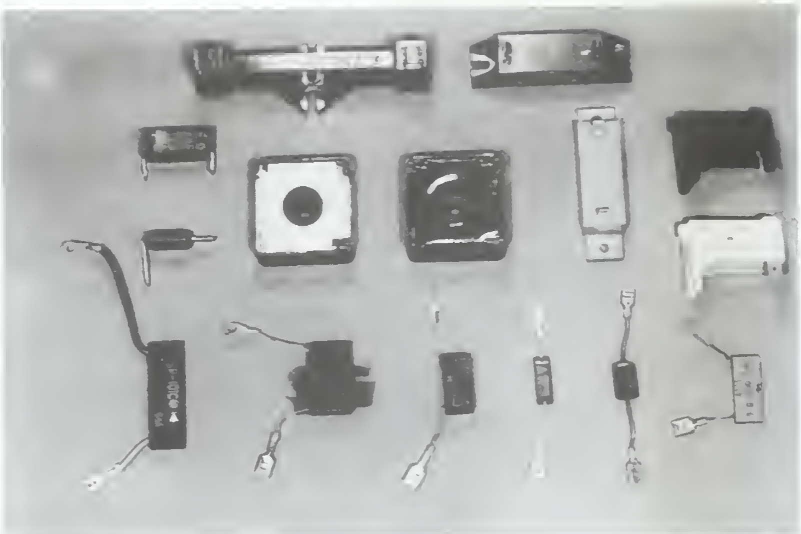


Figure 7-21 Typical high-voltage diodes.

7.5.2 The High-Voltage Diode

A diode (which is also called a *rectifier* because it is used to convert or rectify alternating current into direct current) is a device that will pass current in *one direction only*. In one direction a diode acts as a conductor, while in the other direction it blocks current flow as an insulator. There are many types of diodes, available in all shapes and sizes, from tiny ones about the size of a pinhead to the larger type that are used in microwave ovens. Figure 7-21 shows the variety of diodes used in commercial and residential microwave ovens. In many cases, compatibility in size, mounting configurations, and voltage-current ratings, allow diodes to be interchanged as suitable replacements. A word of caution though: due to different operating characteristics, care must be exercised when substituting one diode for another. Other than the technical documentation on a given diode, or when approved by the respective manufacturer, the only means to determine interchangeability is physical size, terminal and mounting arrangement, and experience. If an interchanged diode becomes too hot to comfortably touch after two to three minutes of operation, it is *not* an adequate substitute.

Figure 7-22 shows the schematic symbol for a diode. Current flow is always from the cathode to the anode, or *against the direction of the arrow*. There is a logical reason for this seemingly illogical symbolism, but it is confusing and irrelevant to the purpose of this explanation. Just remember that the arrow points in the opposite direction to the current flow, and in a half-wave voltage doubler the arrow always points to chassis ground.

Occasionally reference is made to a *stacked diode*. A stacked diode is comprised of a series of diodes encased within one housing, and internally connected so as to better handle higher back voltage.

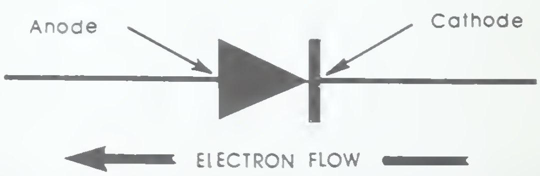


Figure 7-22 Schematic symbol for a diode. (Courtesy of Michael S. Wagner)

In some voltage-doubler systems a *varistor* is employed (either externally or internally) across the high-voltage diode. The varistor has a very high resistance at normal voltages. However, if the voltage across the diode increases due to a surge or spike, the varistor's resistance rapidly decreases providing a shunt path to ground for the potentially damaging surge. (See *Section 9.8* for detailed information on *voltage protection devices.*) Also found across the diode, depending on the model, may be a bleeder resistor or a bleeder-varistor combination.

Types of diode failures to look for, with the accompanying symptoms and methods of testing, are discussed in *Section 12.10.*

7.6 THE HIGH-VOLTAGE CIRCUIT—VOLTAGE DOUBLER OPERATION

In order to effectively analyze a voltage-doubler circuit, it is first necessary to understand the difference between *effective* voltage and *peak* voltage. Measured with a common voltmeter, the voltage in the standard receptacle is 115 VAC (± 10%). The actual voltage alternates through one complete cycle every 60th of a second as shown in the sine wave of Figure 7-23. Since the voltage is continuously varying, the value read on the voltmeter is only the *effective* value of this voltage. The *peak* value that the sine wave reaches is 1.414 times the effective value. So the peak voltage from a standard receptacle would be:

$$\text{Peak voltage} = 1.414 \times 115 \text{ VAC} = 163 \text{ VAC}$$

Knowing peak values and their relationship to effective values is important to understanding the operation of a voltage-doubler circuit.

Voltage-doubler circuits are fed with the stepped up AC voltage from the transformer's secondary winding. Typically, a transformer would step up 115 volts to 2000 volts which would have an approximate peak value of 2800 volts. We will use this value in analyzing the operating sequence of a voltage doubler. Please note that the values of voltages shown are peak, no-load, theoretical values. The actual effective values will be considered after the explanation.

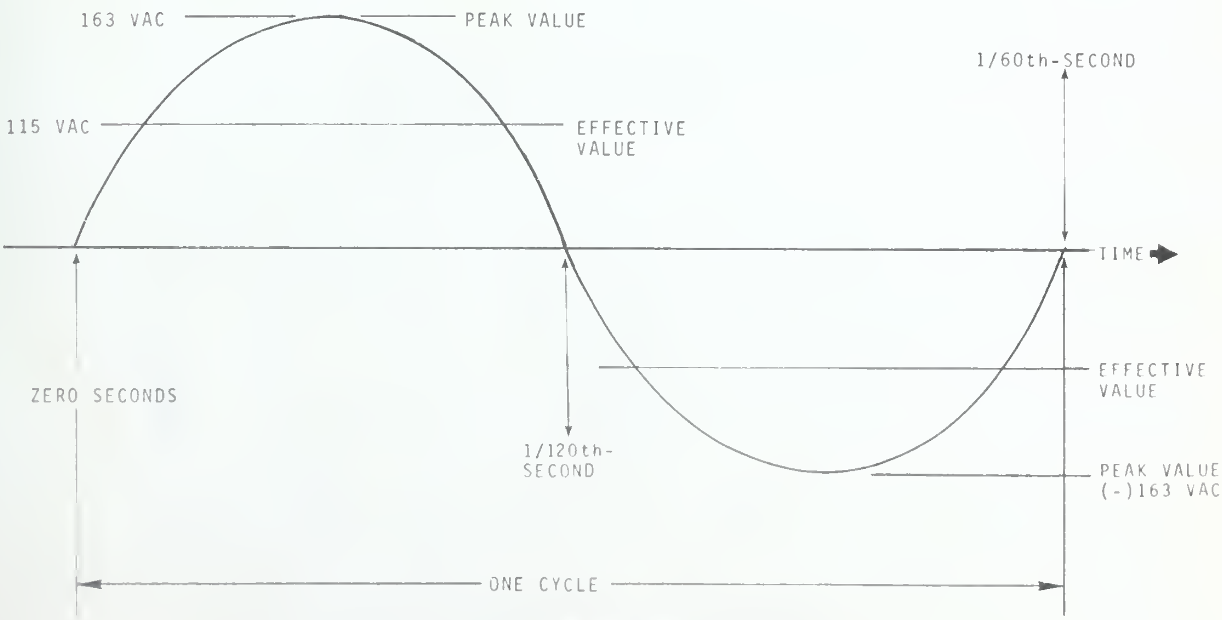


Figure 7-23 60 HZ sine wave.

7.6.1 Half-Wave Voltage Doubler

Refer to Figure 7-24A. During the first positive half-cycle, which is designated on the sine wave graph as "T1," the voltage from the transformer increases accordingly with the polarity shown. The current flows in the direction of the arrow, charging the capacitor through the diode. During the capacitor charging time there is no voltage to the magnetron because the current takes the course of least resistance. In other words, rather than take a path through ground and up to the plate of the magnetron, the current swings up through the diode. The voltage across the capacitor will rise with the transformer secondary voltage to the maximum 2800 volts. As the transformer voltage begins to decrease from its maximum positive value (at time increment "T2" on the sine wave graph), the capacitor will try to discharge back through the diode. The diode, being a one-way street, will not conduct in this direction and therefore blocks the discharge path, so the capacitor remains charged

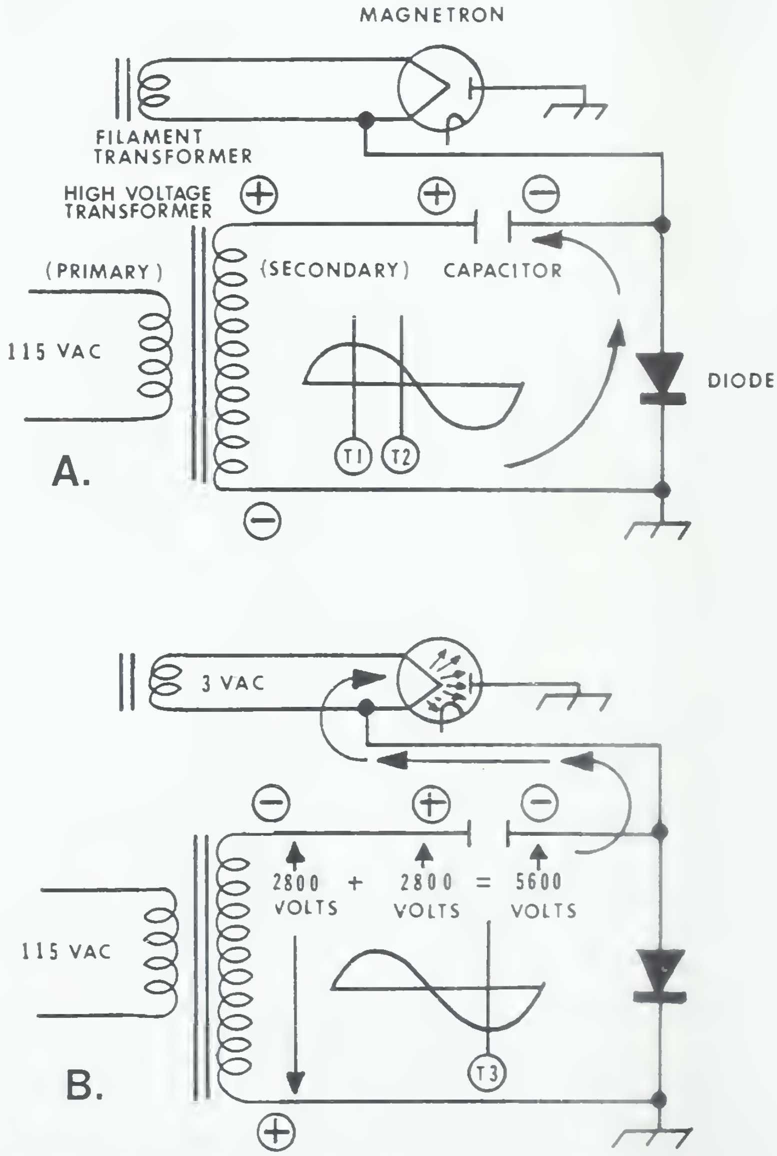


Figure 7-24 The operation of a half-wave voltage doubler. (Courtesy of Michael S. Wagner)

to the 2800 volts. At time "T3" (Fig. 7-24B) the transformer secondary voltage swings into the negative half-cycle and increases in a negative direction to a ***negative*** (−) 2800 volts, with the polarities as shown. The transformer secondary and the charged capacitor are now essentially two energy sources in series. The 2800 volts across the transformer winding *adds* to the 2800 volts stored in the capacitor and the sum voltage of 5600 volts is applied to the magnetron cathode.

There are two fundamental characteristics of this 5600 volts output that should be noted. First, since a voltage doubler is also a rectifier, the output is a DC (direct current) voltage. Second, as waveform "Y" in Figure 7-25B shows, the resulting output voltage that is applied to the magnetron tube is a *pulsed* DC. This is because the doubler generates an output only during the negative half-cycle of the transformer secondary voltage. This also means that the magnetron tube is actually pulsed on and off at a rate of 50 or 60 times a second, depending on the frequency of the line voltage.

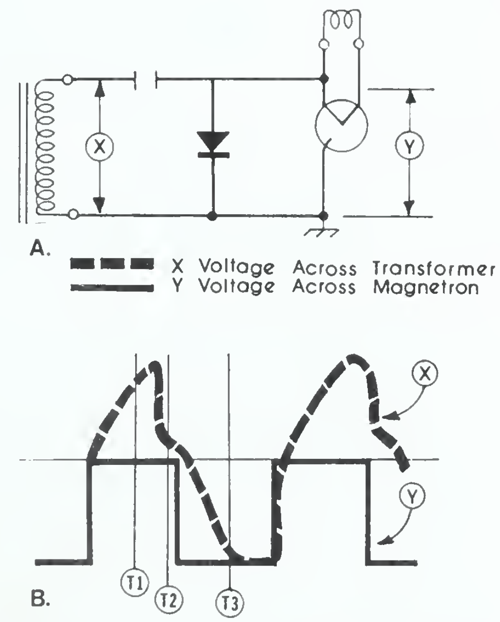


Figure 7-25 Comparison of waveforms at the input and output of the voltage-doubler circuit. (Courtesy of Michael S. Wagner)

7.6.2 Full-Wave Voltage Doubler

The full-wave doubler is simply an extension of the half-wave circuit just explained. This allows for a more simplified explanation. Figure 7-26A shows the charging circuit during the positive half cycle of the transformer secondary voltage. With the polarities as shown, D2 will conduct allowing C2 to charge as indicated by the arrows. In Figure 7-26B the transformer voltage swings into the negative half cycle and the polarities are thus reversed. Now, current flows through D1 which charges up C1. The Diode (D2) does not conduct during this time because it is being *reverse biased* by the polarity of the transformer. The reverse bias effect on the diode (D2) causes it to oppose any current flow. When a diode is *forward biased,* it freely conducts; when it is *reverse biased,* it presents a high resistance to current flow.

Thus, in a full-wave voltage doubler the current flows to a different branch of the circuit each half cycle. Since capacitors C1 and C2 are connected in series, the voltages developed across them combine across the magnetron. Their combined voltage is two times the peak voltage of the transformer secondary. Usually, in actual practice, C1 and C2 are two capacitors in one. This type of capacitor is

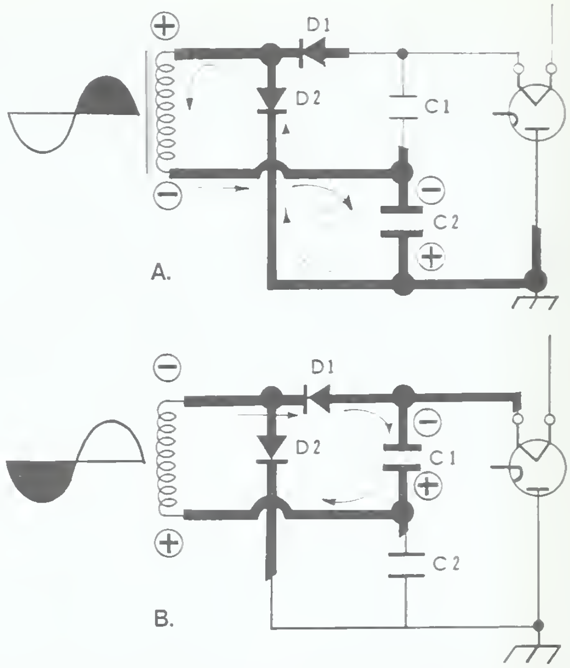


Figure 7-26 The operation of a full-wave voltage doubler. (Courtesy of Michael S. Wagner)

generally called a *dual-rating capacitor* and consists of two capacitors connected and incorporated in one case. The same is sometimes true also with diodes D1 and D2.

Full-wave doublers, although more efficient than half-wave doublers, are not as common in microwave ovens as they once were. Early commercial units used full-wave voltage doublers to drive a single 1000-watt magnetron. However, this design has, by and large, been phased out in favor of a system with two 700 watt magnetrons, each with their respective half-wave voltage doubler systems. These dual-magnetron systems have, in fact, proven to be more practical and of greater reliability than their single-tube predecessors. For example, if any portion of a single-tube unit fails, the entire system becomes inoperative. However, if the same disorder befalls a dual-tube unit, the malfunctioning side can be disabled and oven operation continued at half power (which, to a restaurant owner, is better than nothing) until permanent repairs can be made.

As mentioned earlier, the voltages used in the previous explanations were theoretical. Actually, the doubler circuit, which is inherently inefficient at best, is notably burdened when the magnetron goes into oscillation. The magnetron places a load on the circuit that may decrease the output of a voltage doubler by as much as 40 percent.

A final word about high voltage: The circuits just described *cannot be measured with a normal voltmeter.* If you wish to measure the high voltage, a special high-voltage meter with special leads must be used. **HIGH-VOLTAGE SAFETY PROCEDURES MUST BE CAREFULLY OBSERVED.** However, microwave oven problems can be diagnosed just as, if not more, conclusively and certainly more safely without checking the high voltage. Therefore, **MEASURING THE HIGH VOLTAGE IS NOT RECOMMENDED.**

Control Systems

chapter 8

8.1 INTRODUCTION

If the high-voltage system with the magnetron tube is the heart of a microwave oven, the control system is the brains. The control system consists of methods of timing and means of controlling the high-voltage system; namely the output of the magnetron, thereby controlling the cooking power of the oven. Since any cooking process is dependent on time, the *timer* is a major component of the control section and will be the first to be discussed.

Methods of determining and controlling the overall cooking time range from the basic electro-mechanical timer, to the solid state pushbutton timer, to the elaborate electronic control panels with their multiplicity of functions, features, and programs—some even talk to you. Figures 8-1 through 8-4, 8-7 and 8-8 show some different types of timers with their progressive complexity.

8.2 TIMERS

The typical basic **electro-mechanical dial timer** (Fig. 8-1) uses a constant speed electric motor (usually 117 VAC) which controls a set of contacts by means of a gear and cam arrangement. The contacts, which control the circuit that provides current to the primary of the high-voltage transformer, are closed by turning the knob on the timer motor shaft to a selected time on the dial. Voltage to the timer motor is supplied through a circuit that includes the closed timer contacts. A cam, attached to the shaft, keeps the contacts closed as the whirring little motor turns the geared-down slow moving shaft back to its zero-time mark where a notch in the cam allows the contacts to open and the cooking stops. This is usually accompanied by the sounding of a bell, the striker of which is mechanically driven. The distance between the striker and the bell housing (this distance determines the clarity of the ring) can usually be adjusted by simply rotating the bell housing on its off-center mount.

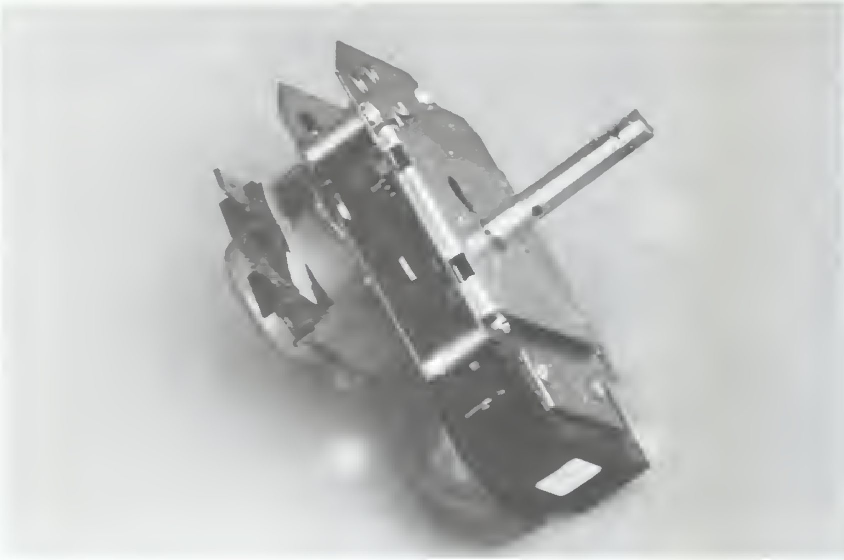


Figure 8-1 Basic electro-mechanical timer.

Some models are equipped with two dial timers; typically, a 5-minute timer with its expanded scale allows for settings down to about 15 seconds, and a 30 minute timer enables more extended cooking times.

Also driven by an electric motor, and energized through its internal contacts is the **digital timer** (Fig. 8-2). This type of timer combines the advantages of the two dial timers. The timer knob, when pushed in and rotated, engages the first of a series of vertical plastic wheels, each with digits imprinted upon its edge. The first wheel rotates through 59 seconds then engages the second wheel which registers 1 minute, and so on. Rotating the thumbwheel on the left-hand side adds time in 10-minute increments, allowing for cooking times of up to 99 minutes and 59 seconds. Pushing in and rotating the timer knob activates the timer contacts which open or close the cook circuit. When the timer reaches the end of the selected cooking time, the bell rings and the timer switch contacts open, deactivating the timer motor and the cook circuit.

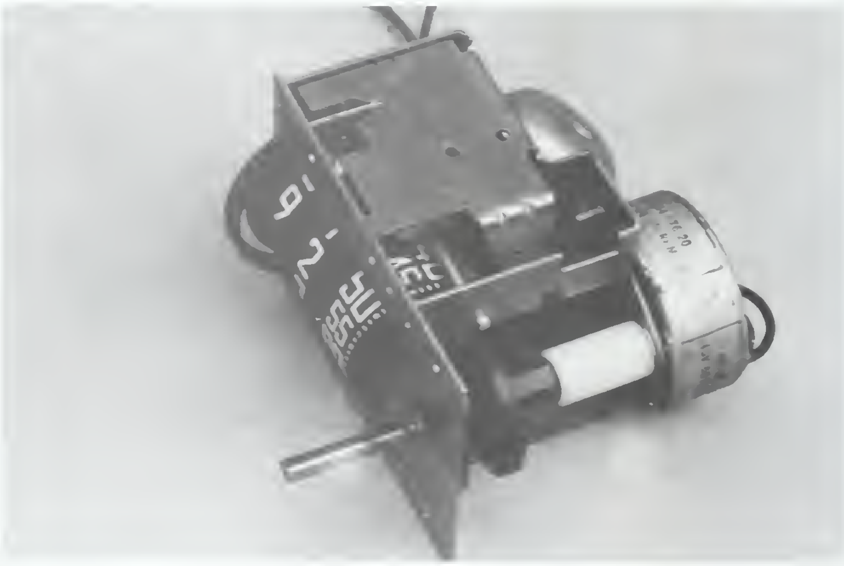


Figure 8-2 Digital timer.

8.3 COMMERCIAL TIMERS

Next, in a progressive look at timers is the **electro-mechanical pushbutton timer** (Fig. 8-3). This type, found mostly in older commercial models, is activated when one of several buttons is pushed. The action of the button locking in closes the timer contacts which energize the cook circuit and the timer motor. The motor slowly rotates a camshaft, each nylon cam on the shaft corresponding to a button. Each cam has a lobe which, as the camshaft slowly rotates, will raise and release a trip rod, disengaging the timer contacts and releasing the respective button. The actual time settings are determined by the adjustable position of the lobes on the outer perimeter of the individual cams. The cooking time is the time required for the lobe to travel far enough to disengage the button, thus ending the cook cycle. A coiled spring returns the shaft to its starting position. If a button fails to disengage, a *safety-release solenoid* is energized which deactivates the circuit. Opening the oven door also releases the button by means of this solenoid.

Superseding the mechanical pushbutton timer is the **solid-state pushbutton timer** (Fig. 8-4). In order to analyze the operation of the solid-state timer in a way that will be generally understood, the circuit description which follows has been simplified to the extent that an accurate explanation will allow. Also, this is an area where many manufacturers (mostly U.S.) feel, for reasons that some would dispute, that expanded information in the form of schematics and component data is not needed by those in the field. So, knowledge of these circuits is scarce and troubleshooting is limited. However, for purposes of this explanation, the following generic circuit demonstrates actual timing circuits that have been ascertained from

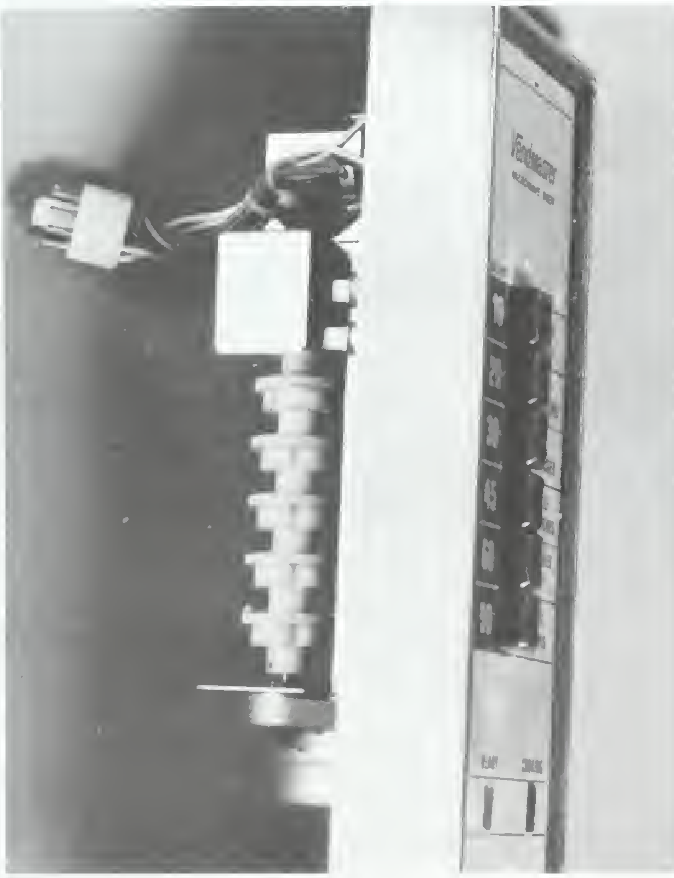


Figure 8-3 Electro-mechanical pushbutton timer.

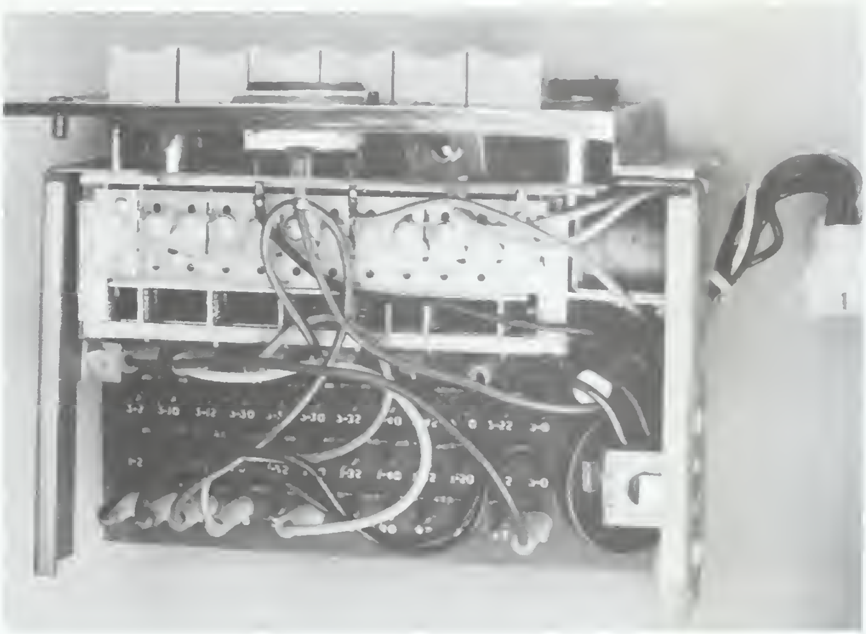


Figure 8-4 Solid-state pushbutton timer.

behind the corporate curtain. The circuit configuration depicted here is not that of any one timer, but is representative of many commercial timers of this type used by several manufacturers, such as *Litton, Amana* and *Sharp.*

Refer to Schematics #1 through #8 of Figure 8-5. When, for example, timer button number 6 is depressed, it locks in and initiates the following sequence of operations.

Schematic #1

Current flows through the closed "B" set of contacts in the double switch bank of button number 1, illuminating the cook light and energizing the cook relay. The current flow through the cook relay coil causes it to become magnetic so that it pulls its contacts into a closed position. (See *Section 8.10* for additional information on the *cook relay.*)

Schematic #2

The closed cook relay contacts provide a current path to the primary of the high-voltage transformer—the cooking cycle begins. At the same time current begins flowing, in alternate half cycles, through diode D1 and through the current-limiting resistor R1. The effect of the current is to charge capacitor C1.

Schematic #3

Capacitor C2 also begins to charge, but its charge path is restricted by a series of resistors (which resist current flow). This series of resistors is the timing circuit. Since resistors in series add to the overall resistance to current flow, the time required to charge C2 is dependent on the number of resistors in the timing circuit. The number of resistors placed in the series depends on which button is pushed. (Each button is adjusted to a desired preset time by connecting a corresponding jumper wire to a selected terminal post, each post serving to either add or subtract resistors from the timing circuit with respect to that particular button.) Button number 1 is set for the longest time, so all of the timing resistors (plus the adjusted value of variable resistor R7) are placed in the circuit through its "A" set of contacts.

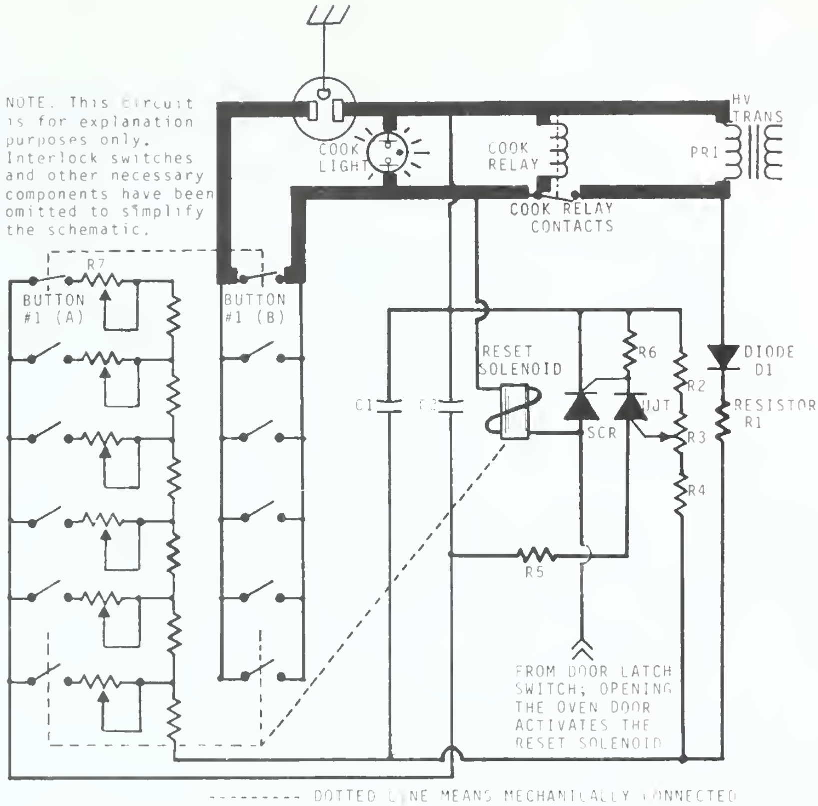


Figure 8-5 Schematic #1.

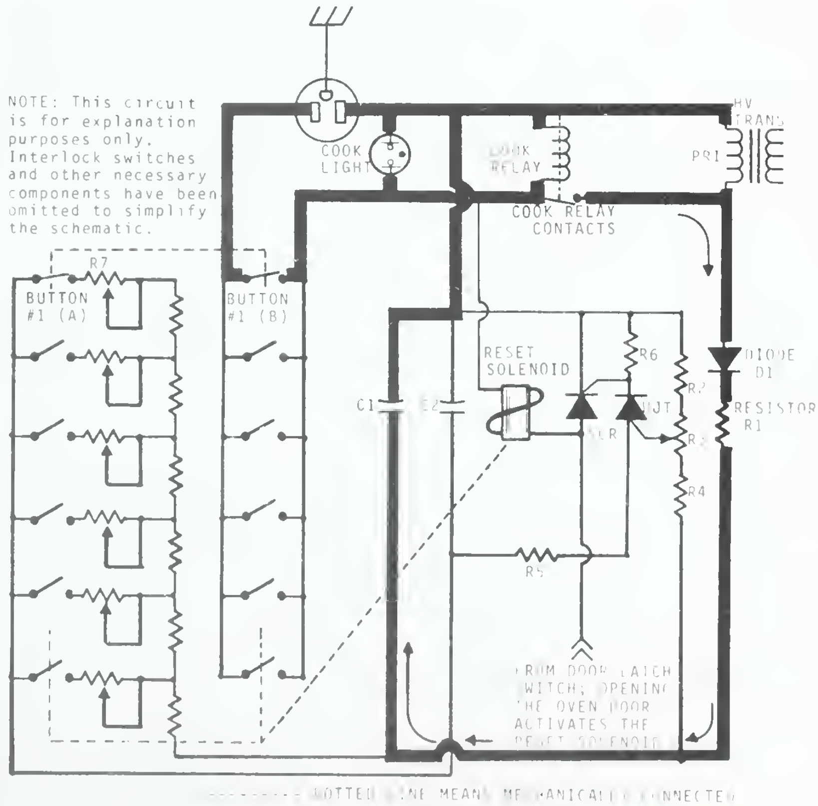


Figure 8-5 Schematic #2.

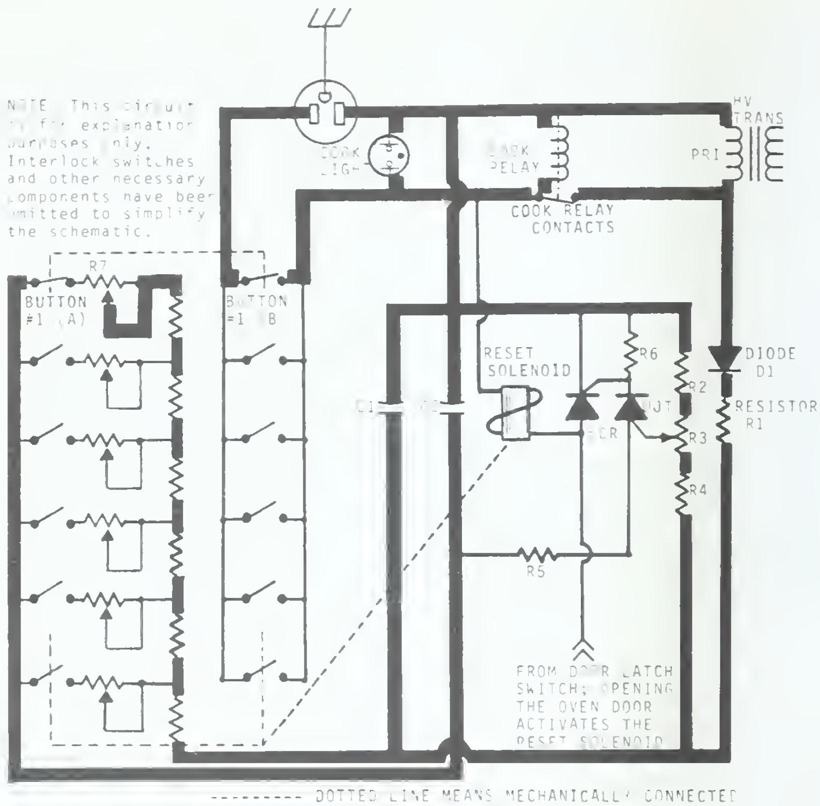


Figure 8-5 Schematic #3.

At this point the *unijunction transistor* (UJT) is being held in an "off" condition by a bias voltage. The bias voltage, which is developed across R3 from the stored voltage on C1, creates the necessary polarities around the UJT to keep it from conducting. Capacitor C2 must charge to a high enough voltage to overcome this bias voltage, but its charge time is slowed by the timing resistors. The time it takes C2 to charge up sufficiently to overcome the bias on the UJT is what determines the cooking time of the oven.

Schematic #4

C2's charge finally grows stronger than the bias voltage and the UJT conducts. This creates a voltage across R6 that turns "on" the *silicone-controlled rectifier* (SCR).

Schematic #5

The conducting SCR provides a circuit to the *reset* (or *cancel*) solenoid and to a buzzer (not shown). The action of the reset solenoid mechanically releases the engaged button, ending the timing sequence and opening the circuit to the cook relay. The cooking stops.

8.4 ADD INTEGRATED CIRCUITS

An *integrated circuit* (Fig. 8-6) is essentially an entire printed circuit board, with all of its integral components, compressed into and integrated onto a tiny silicone "chip" housing. Figure 8-7 shows a simplified schematic of a timing circuit that is

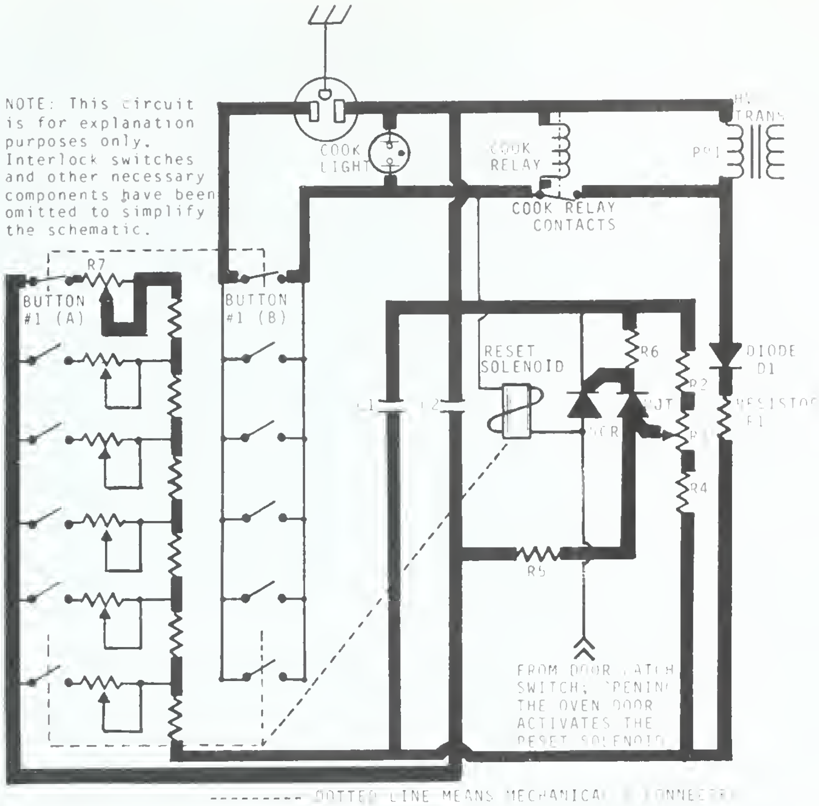


Figure 8-5 Schematic #4.

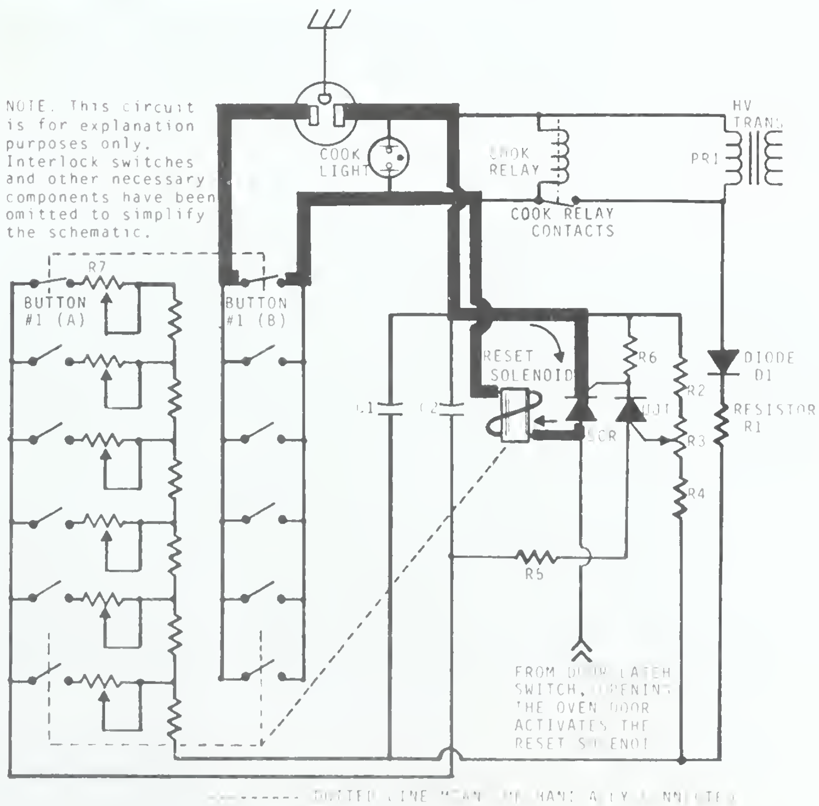


Figure 8-5 Schematic #5.

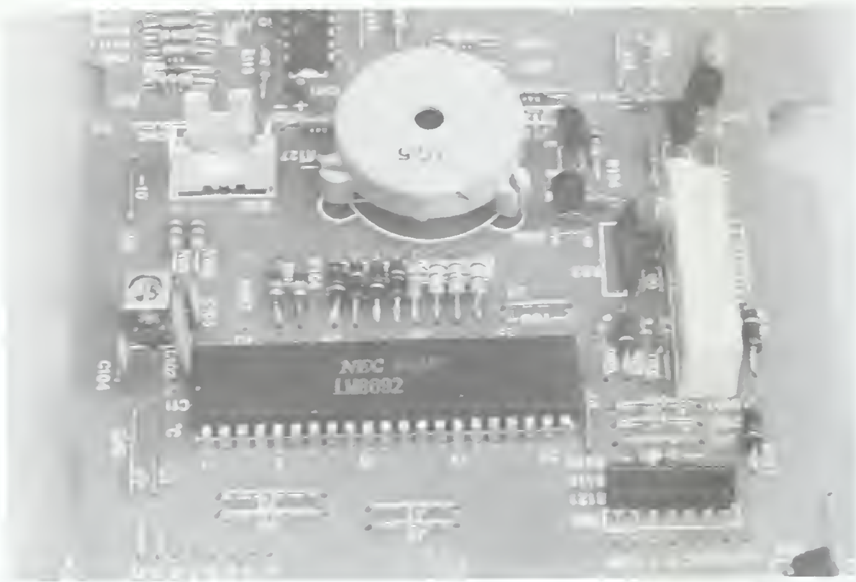


Figure 8-6 Typical integrated circuit.

used, in one form or another, in many commercial models. Notice in this case how several functions are incorporated within one integrated circuit.

When button number 2 is pushed, one set of contacts (not shown) in its double (or triple in some models) switch bank provides a circuit to the cook relay; the other set of contacts provide the circuit shown. A DC current flows through the closed contacts to charge capacitor C1. The capacitor is charged through a series of resistors, the number of which determine the charge time.

When C1 charges sufficiently, IC1 senses this and energizes the coil of the release solenoid. The solenoid mechanically releases button number 2, opening its contacts and ending the cook cycle.

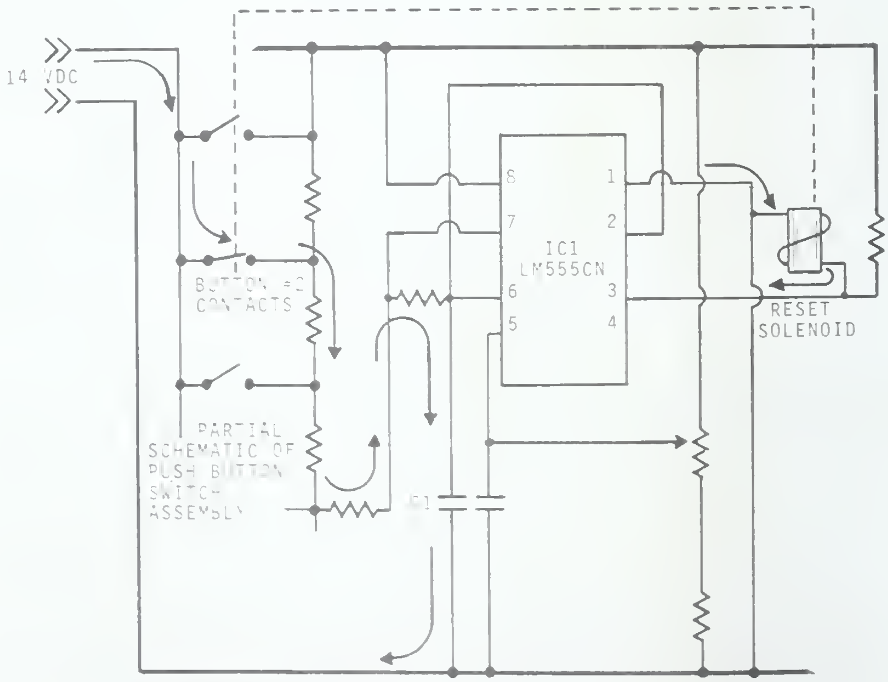


Figure 8-7 Commercial timer with an integrated circuit.

8.5 MICROPROCESSORS AND COMPUTER ELECTRONICS

Advanced engineering in digital technology has produced timers and controllers for commercial and residential models that are essentially mini-computers (Fig. 8-8). These microcomputer circuits are capable of extensive programming modes and computer functions such as memory, calculation, data processing, output control, and even voice synthesizing. But, while sophisticated features and options are common, schematic data and parts information on the digital circuits are not. Some manufacturers, such as *Sharp* and *Panasonic,* do provide limited technical data in their respective service manuals which serve the needs of experienced authorized servicers. However, this high-level electronic data will not be elaborated on here. The purpose of this text is to provide basic principles on the operation of a microwave oven. The complexity and diversity of these microprocessor logic circuits go beyond this objective. Troubleshooting these digital programmer circuits can be accomplished, to a very limited degree, by looking for obvious problems and checking certain common components. However, extensive servicing at the board level is not deemed practical for the following reasons: 1) If you have the advanced training in computer electronics that it requires, you should be repairing computers. 2) The numerous and diverse circuit and connector configurations would necessitate a bevy of test harnesses, rigs, and jigs. 3) Special state-of-the-art functional analyzing equipment is needed. 4) The lack of schematics and component data makes major troubleshooting virtually impossible. Schematics that are available seldom reference voltage readings or waveforms. 5) The price of a reconditioned board from the manufacturer is usually not much more than the cost of the labor involved to trouble-shoot and repair the board yourself.

The reasons stated above make a good case for replacing a defective digital control board, rather than troubleshooting it. A problem arises though, in determining whether an operational failure is emanating from within the control circuitry or the external components it controls. This can be more than frustrating when the schematic shows only an empty box labeled "control circuit" and the leads from the other components simply "dead-end" there. Common symptoms and troubleshooting techniques that minimize the aggravation in this regard are outlined in *Chapter 13,* and *Part 5.*

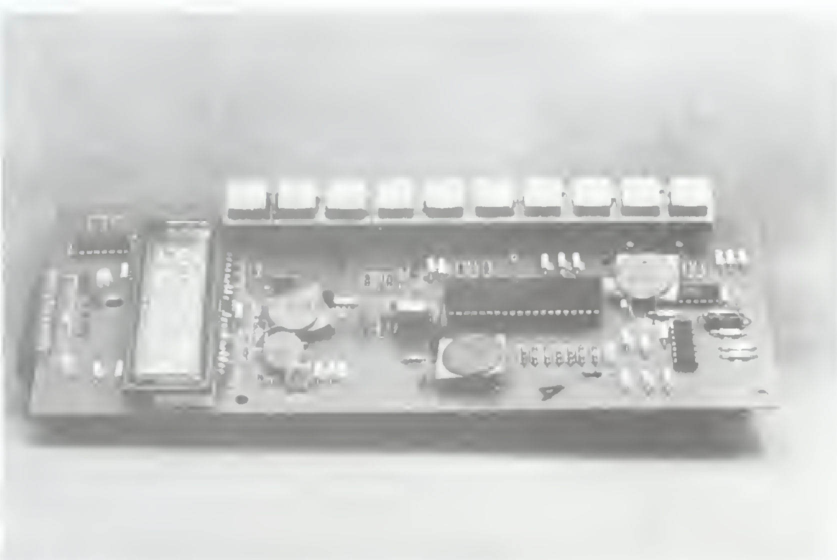


Figure 8-8 Commercial timer with a microprocessor.

8.6 PRINTED CIRCUIT BOARD REPAIR CONSIDERATIONS

As mentioned previously, manufacturers such as *Sharp, Panasonic, Quasar, Hitatchi, Toshiba, Sanyo,* among others, do provide schematic information. Your decision as to whether or not to service these units at the board level will depend on your circumstances, experience, ability, available test equipment, and so on. A few factors to consider when repairing these control units are:

1. Ground yourself, your soldering iron, and work bench; static electricity in clothes and other items can damage certain static-sensitive control panel components. These are the MOSFET (metal oxide semiconductor field-effect transistor) type integrated circuits that, due to their field effect characteristics, are very sensitive and susceptible to damage from electrostatic discharge. Therefore, **do not touch any part of the circuitry on the back of the control board,** unless you are properly grounded. Figure 8-9 illustrates a static-control wrist strap that can be worn to avoid damage to static-sensitive components. Additional precautions to be taken:
   - A. In lieu of a static-control wrist strap, touch a grounded metal chassis just before touching any electronic circuitry to discharge any static charge.
   - B. Place sensitive electronic control boards on a conductive surface such as aluminum foil. Do not place them directly on areas that may hold a charge, such as a carpet, workbench, or cabinet.
   - C. Be aware of the fact that certain solder suckers will generate up to 20,000 volts of charge when triggered. Only anti-static solder suckers should be used for removing these static-sensitive types of integrated circuits.

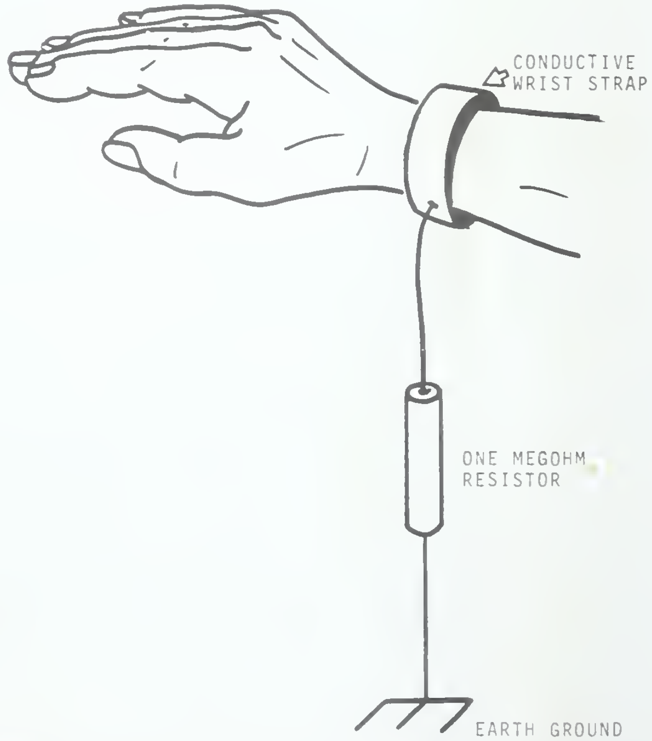


Figure 8-9 Static-control wrist strap. (Courtesy of Michael S. Wagner)

D. Replacement ICs are packaged in special conductive foam or aluminum foil. So, just before removing the IC, neutralize any charge by touching the foam (or foil) packaging with one hand and the intended printed circuit board with the other. Also, be aware that minimal amounts of movement, such as brushing your clothing across an object, can generate static electricity, so keep movement to a minimum.

E. Use only anti-static sprays. Freon sprays can generate more than 5,000 volts of static electricity.

2. If the oven must be plugged in while troubleshooting, *first* disconnect and insulate the wire to the primary of the transformer, thereby disabling the high-voltage section.
3. If the control panel is separated from the oven while testing, a common ground must be maintained between them.
4. Appropriate test rigs must be fabricated to simulate external switches and other oven components.
5. A 30 watt soldering iron with a grounded tip (to prevent leaking current), and a single-beam oscilloscope with a frequency range from DC to [at least] 10MHz will also be required.

8.7 DOMESTIC ELECTRONIC TIMERS

During the period of 1975-76, manufacturers added an innovation to their microwave ovens that proved to be a boon for the servicer, a bust for the manufacturer, and a time bomb for the consumer; the *capacitive touch* or *static discharge* control panels (Fig. 8-10). Theoretically these circuits should have been extremely reliable and enduring. With no moving parts and no switch contacts, they used the capacitance that exists between a human body and an electric circuit to provide the input signal. Through the normal course of events, our bodies are constantly coming into contact with numerous and different materials. In each case there is a transfer of electrons, so, usually unbeknownst to us, we develop and maintain an electric charge within our bodies. Dry weather (relative humidity less than 30%) tends to multiply this accumulation and static charges can build up and become quite noticeable. For example, walking across a carpet in a low-humidity environment can generate a static charge of up to 35,000 volts. The first metal door knob you touch makes you painfully aware of that stored charge, by the jolt of the electrostatic discharge. With this *static* charge or stored body electricity (usually well below the human sensing threshold of 3000 volts), our bodies are like charged capacitors.

8.7.1 Glass Touch Panels

Figure 8-11 shows a sectional view of a glass touch panel and printed circuit board. Certain areas on the front side of the glass are plated with a special coating of tin oxide or platinum, forming keypads. These coated areas also act as *electrodes.* Corresponding areas on the opposite side (rear surface) of the glass are coated with silver paint or carbon to likewise form electrodes. Each front-side electrode along with the electrode directly opposite it, on the rear surface of the glass, forms a capacitor, with the glass panel serving as the common dielectric. A constant operating voltage is supplied though a *common* electrode which ties in with each of the capacitor circuits. Since a person's body is like a capacitor, when that person touches a key pad, their body capacitance is added to the capacitive circuit of that respective pad (Fig. 8-12). The change in capacitance causes a variation in the voltage level that

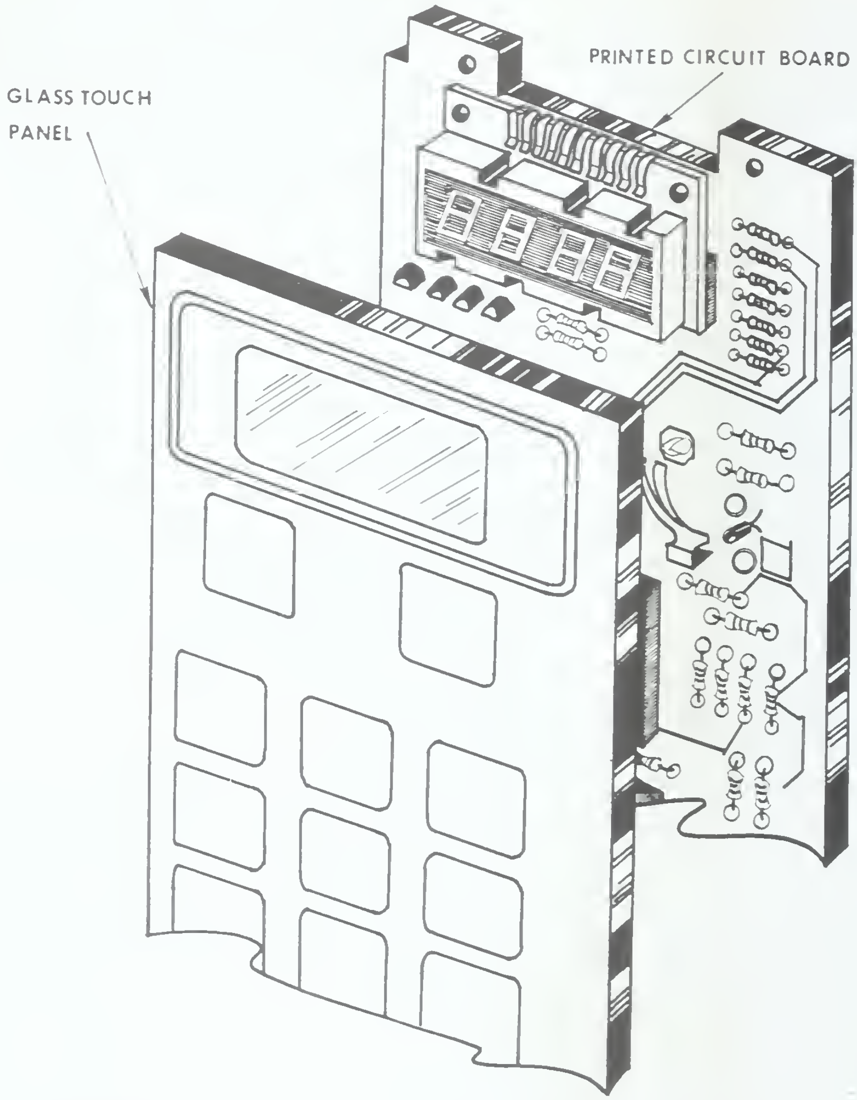


Figure 8-10 Capacitive (glass) touch panel. (Courtesy of Michael S. Wagner)

is detected, through the spring contacts, by the appropriate terminals of the microprocessor. The microprocessor is then able to determine which pad is being touched and responds accordingly.

These glass touch panels were simply too sensitive to be reliable, and are fast becoming extinct. At one time, when replacing one of these panels out of warranty, the defective unit could be sent back for (approximately enough) a "dud fee" (the manufacturer buys back the defective unit for possible reconditioning). In most cases, the manufacturers now no longer want them back.

8.7.2 Membrane Switch Panels

The glass (static-discharge) touch panels are being replaced by the *membrane,* or *mylar touch* panel. Figure 8-13 shows a sample of a membrane switch panel that was supplied to the *Whirlpool* corporation by *Mepco/Centralab, Inc.* A much more reliable and practical means of providing input to the microprocessing unit, these

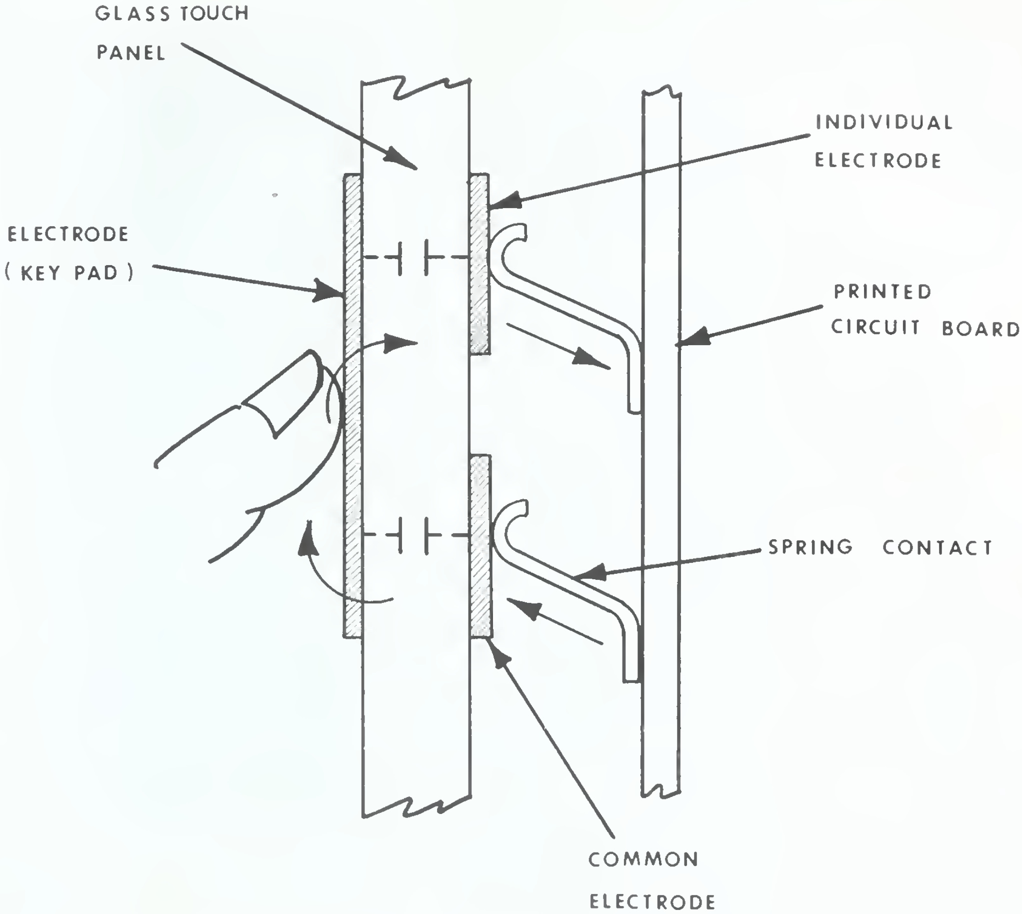


Figure 8-11 Sectional view of a capacitive-touch control panel. (Courtesy of Michael S. Wagner)

key units require only a gentle press to actuate a set of silver or tin-plated copper contacts (Fig. 8-14), thus providing data to the control board.

Figure 8-15, on page 98, (illustration and explanation supplied courtesy of *Mepco/Centralab, Inc.*) shows the two basic types of membrane switch panel construction; the rigid base type, and the film-base type. In each case, three switch layers constitute the basic switch package. The top layer is made of a tough flexible polyester membrane with moveable screened contacts. The middle layer is the adhesive spacer that provides the gap between the moveable contacts and the stationary switch circuits. The bottom layer is either a polyester film substrate (or support) or printed circuit board base, depending on the model.

Whereas the glass capacitive touch panel and its control board were designed as one unit and replaced as such, the membrane switch panel and its associated

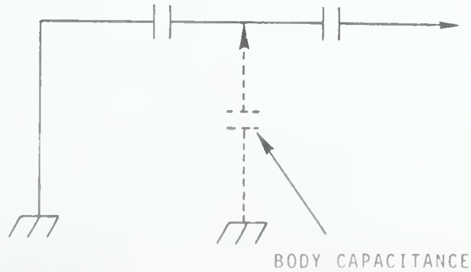


Figure 8-12 Schematic equivalent of a capacitive-touch circuit.

Figure 8-13 Sample of a membrane switch panel.

control circuitry are usually available separately. This holds down the cost of repair, but increases the difficulty in troubleshooting. For example, a symptom of erratic programming could be caused by either the switch panel or the control panel. A design feature in some models that helps to isolate programming problems is the *self test program*. This involves programming in a sequence of numbers by which the control panel initiates a self-diagnostic mode. In this mode, the control unit checks its various functions as well as other associated circuitry, and responds with a code of some sort which translates into the results of the self-diagnosis. In lieu of a self-test feature or as an ultimate solution, many manufacturers suggest the "replacement method". In other words, replace the *control* panel and if the problem still exists it must be in the *membrane touch* panel—or possibly both. So you replace the touch panel and it works. The oven is repaired but now you have a problem; an expensive unused *control* panel. You can keep it in stock, which, after a few "replacement methods", can become quite an expensive arrangement both in money and storage space. Another option is to send the control panel back to the distributor. If they will take it back, you will pay up to 20% of its cost as a restocking fee. While this fee can occasionally be compensated for, it too will eventually add up to an impractical procedure. *Chapter 13* offers some practical alternatives and modifications to the "replacement method". *Appendix I, "Touch Panel Testing and Reference Matrix Diagrams"*, will also be of help in this regard.

As explained previously, details concerning the integrated parts of microprocessors and digital circuits that are used in microwave ovens are vast, progressively varying, and not necessary to the purposes of this text. This information is equally unnecessary to the understanding and troubleshooting of microwave oven

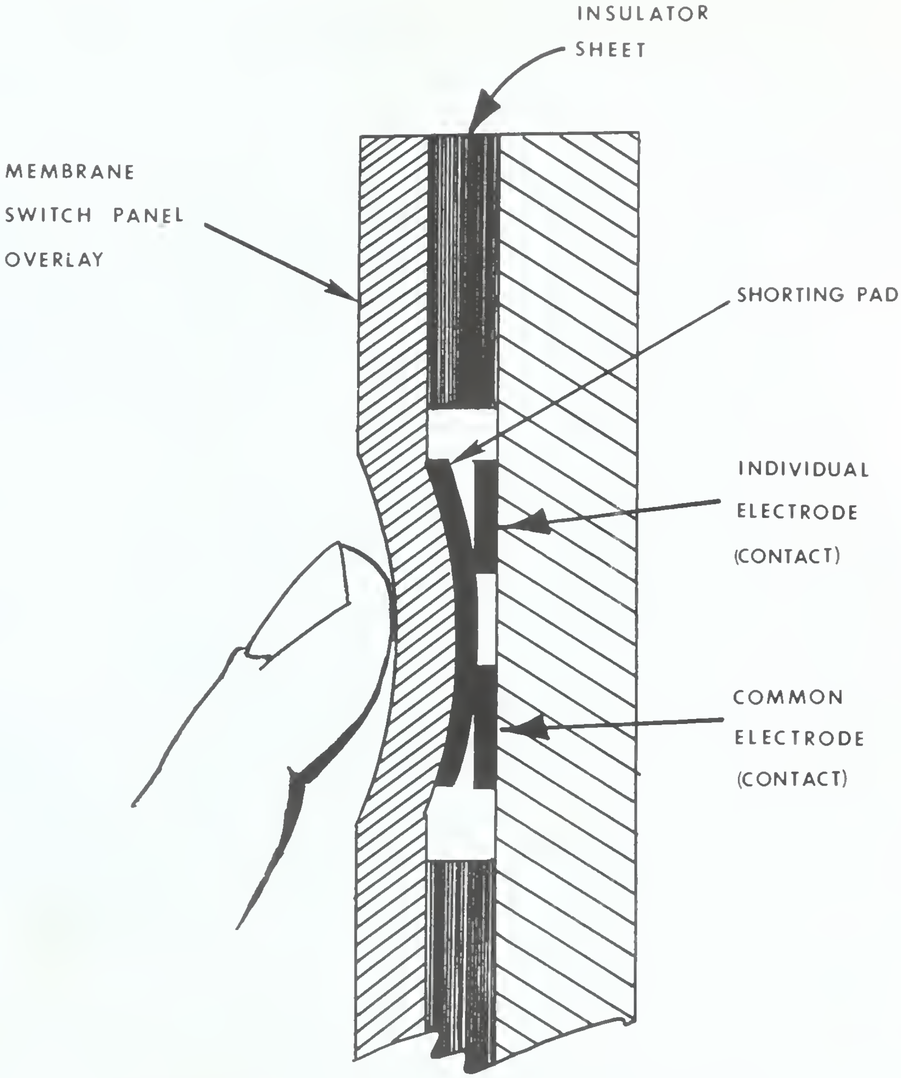


Figure 8-14 A soft touch produces "micro-motion" switch closure. (Courtesy of Michael S. Wagner)

control systems. Specific data regarding a particular model may, in some cases, be obtained from the respective service manual or manufacturer.

However, in order to demonstrate the fundamental theory of operation and to provide an effective overview of a typical control system, Figure 8-16 offers a representative block diagram. A brief explanation of each block is as follows:

Pulse Oscillator—Establishes the speed at which the microcomputer processes programming.

Display Circuit—From signals generated by the microcomputer, the appropriate segments are energized to form visible display characters.

Random Access Memory—A feature not found on all models, this allows for customer-programmable recipes. Some models provide a backup battery so stored data will not be lost in the event of a power failure.

Touch Panel Key Board—The means by which the user provides input data to the microprocessor.

Initialization Circuit—Resets the system when power is first applied to the unit.

D-A Converter and Comparator—When the temperature probe is in use, *DIGITAL*

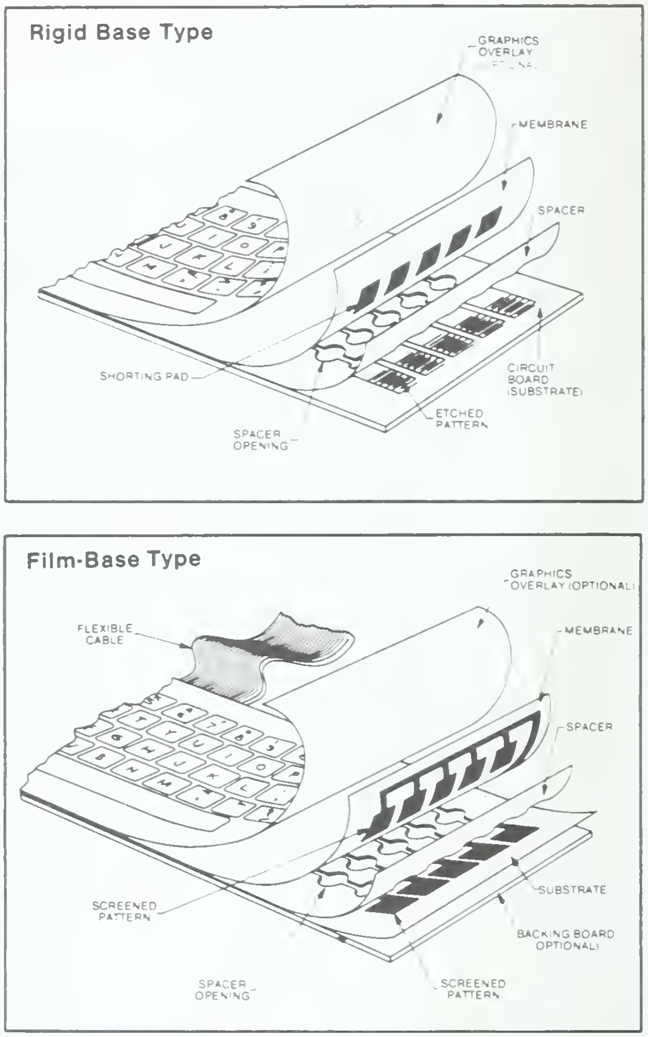


Figure 8-15 Membrane switch panel construction. (Courtesy of Mepco/Centralab, Inc.)

signals are sent out from the microprocessor that correspond to different temperatures. In this circuit, these digital values are converted to a *ANALOG* values. The analog voltages are then compared to voltage variations (derived from variations in the resistance of the *thermistor* in the tip of the temperature probe) of the temperature probe. Thus the microprocessor knows, at any instant, the temperature of the food being cooked and can adjust the cooking time accordingly.

Buzzer Drive—Generates the signal which sounds the buzzer at the end of the cooking process, or other sequence.

Power Supply Circuit—Rectifies AC and regulates DC voltages in order to produce the necessary operating voltages for use in the control circuitry.

Microcomputer—Contains a microprocessor combined with input and output interface devices, and other elements to compute and process the various input data and generate appropriate output signals. The signals that the microprocessor understands are called *digital* signals. These signals are made up of a sequence of pulses or bits within a specific period of time. When a pulse is present, a "high" (or "1") exists. The absence of a pulse is represented by a "low" (or "0"). Information is derived from the "high" and "low" signals based on their arrangement and combination within a specific time period. Thus, the digital circuit is controlled by these "high" and "low" signals.

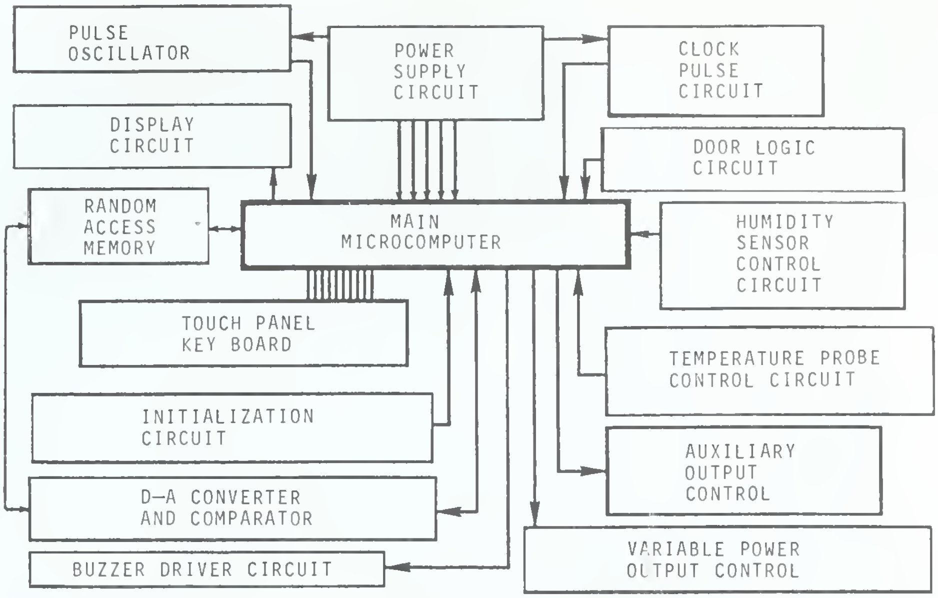


Figure 8-16 Representative block diagram of a microcomputer-controlled system.

Clock Pulse Circuit—Generates a synchronized clock pulse at the frequency of the line supply voltage (i.e., 60/50 hz). This serves as a reference for the microprocessor in its various timing functions.

Door Logic Circuit—Through an external switch or by other means, a signal is sent to the microprocessor indicating that the oven door is either open or closed.

Humidity Sensor Control Circuit—Through external circuitry, this circuit reads the relative humidity within the oven cavity and provides input data to the microprocessor accordingly.

Temperature Probe Control Circuit—Through an external probe, this circuit detects the temperature of the food in which the probe is inserted and feeds that information to the microprocessor.

Auxiliary Output Control—Controls the blower and stirrer motors, cavity light, oven relays, and various other external components, depending on the model.

Variable Power Output Control—Based on signals from the microprocessor, this circuit controls the duty cycle of the *triac* or *high-voltage relay* (depending on the model). The on-off timing within a specific duty cycle determines the average output power of the microwave oven.

8.8 CONTROL TRANSFORMER

Control transformers, comparatively small in size and output, are step-down transformers that supply power to both domestic and commercial control units. These transformers, also called *low-voltage* or *control* transformers, usually have several secondary taps which provide an appropriate selection of control voltages as required by the various electronic control panels (typically, 2.5, 12–13, 16–18, 20–24, and 32–36 volts AC, depending on the make and model). Figure 8-17 shows three common control transformers, which, depending on the model, may be mounted separately or directly on the printed circuit board. It is not unusual to find these transformers isolated within the assembly of other induction-type devices. For example some models use a *transmotor* (Fig. 8-18). This combination blower motor-transformer is simply a motor with a secondary winding that provides stepped-down voltages to the controller.

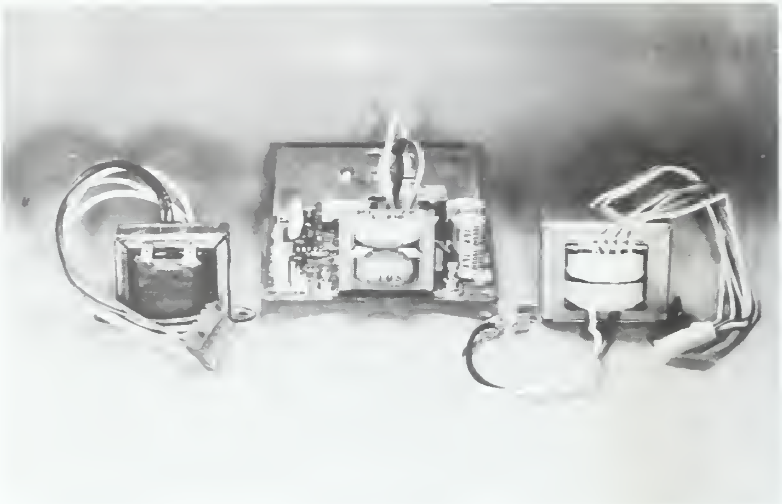


Figure 8-17 Typical low-voltage transformers.

In some commercial models the control voltages are supplied by an *auto isolation transformer*. The auto isolation transformer serves two purposes: The primary is an auto transformer which facilitates a voltage adjustment that matches oven components to the available line voltage. The isolated secondary winding provides a stepped-down control voltage to the electronic timer.

Another arrangement used, primarily by *Litton,* in commercial models is the *auto-filament transformer* depicted in Figure 8-19. This transformer steps down a primary voltage supply of 240 volts AC to approximately 4.5 volts AC, which is used to heat the magnetron filaments. A center tap on the primary winding provides power to those components which require 120 volts AC, such as the pushbutton timer.

8.9 STANDBY, IDLE, AND COOK

Some commercial and domestic microwave ovens use an additional timing circuit; not to time the cook cycle, but to time the *idle condition.* Normally the oven is in the *standby condition* (as though no power were applied), then when the door is opened,

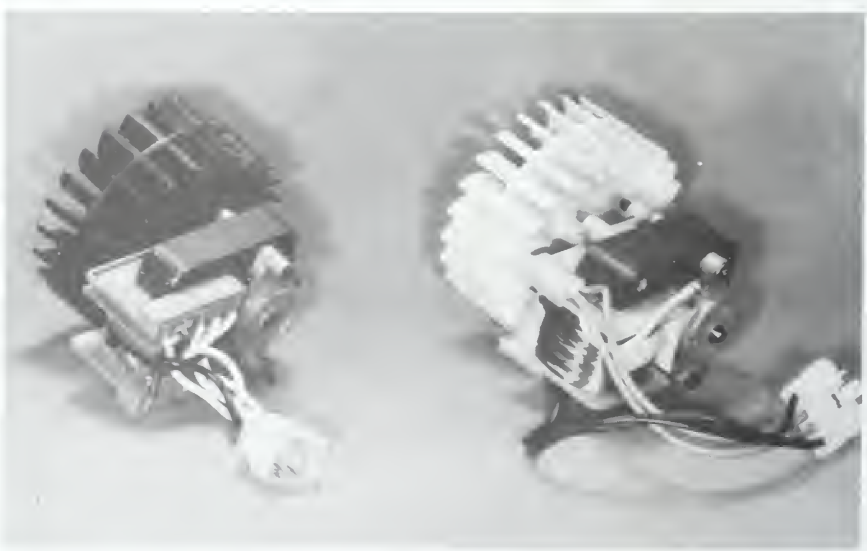


Figure 8-18 Typical transmotors.

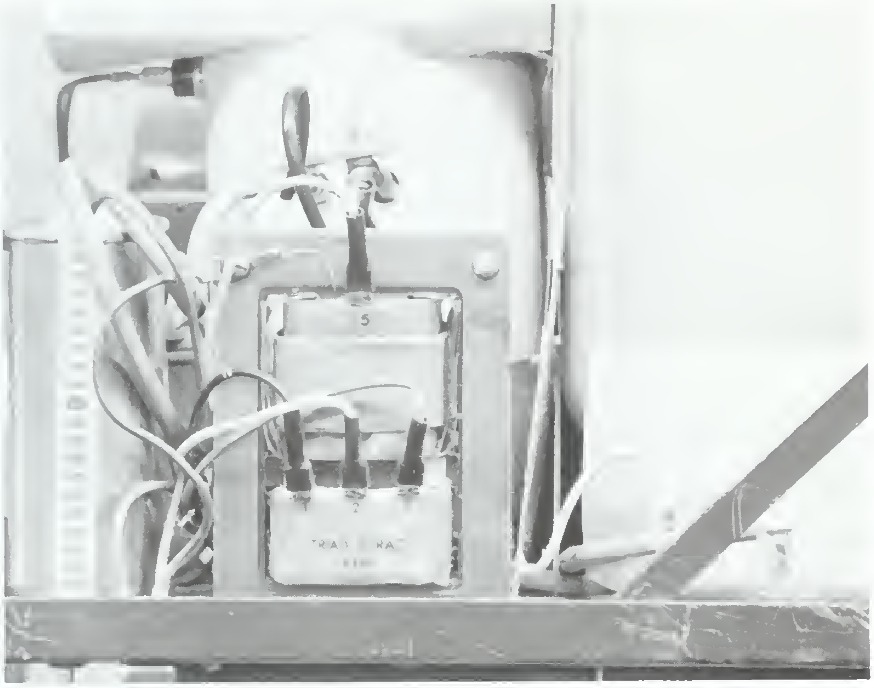


Figure 8-19 Auto-filament transformer.

or (on some models) closed from an open position, the oven comes up to the idle condition. The operations that occur in this state of readiness (varying with different models), include the following: the blower motor runs, the cavity lamp comes on, the stirrer motor rotates, power is applied to the control circuitry, and power is applied to the filament transformer which in turn provides filament voltage to the magnetron.

Once in the idle mode, which is initiated through the action of a door switch, the oven awaits the additional executions that will begin the cook mode. Some older magnetron tubes require a brief warm-up, so, many models provide a pre-cook delay of three to 10 seconds. During this time, filament voltage is applied, and in some models momentarily increased (through what *Litton* calls a *programming relay*), to warm up the tube. Newer "hot" tubes do not require a warm-up. After the cook cycle ends the oven reverts to the idle (or ready) condition for a period of time which is determined by a holding circuit. If about 60 to 90 seconds elapse with no additional operations initiated by the user, the oven returns to the standby mode. Older models use a *thermal relay* which maintains the holding circuit through its normally closed contacts. After about 60 seconds, a heater within the relay causes the thermally activated contacts to open, shutting down operations, and returning the oven to the standby mode.

Thermal relays have since been replaced by more reliable solid state components and associated timing circuitry. Figure 8-20 shows, from left to right, a thermal *holding* relay, a solid-state 10-second *warm-up* relay, and 60-second *shut-down* relay. More recent commercial and residential models incorporate these functions into the solid-state circuitry of the main control panel or associated circuitry. Following are two examples of these electronic start-up, holding, and shut-down circuits.

EXAMPLE 8.1: Start-up, Holding, and Shut-Down Operation

While, in this first example, the description of operation and schematic diagram are that of one popular *Sharp* commercial model, the basic principles of

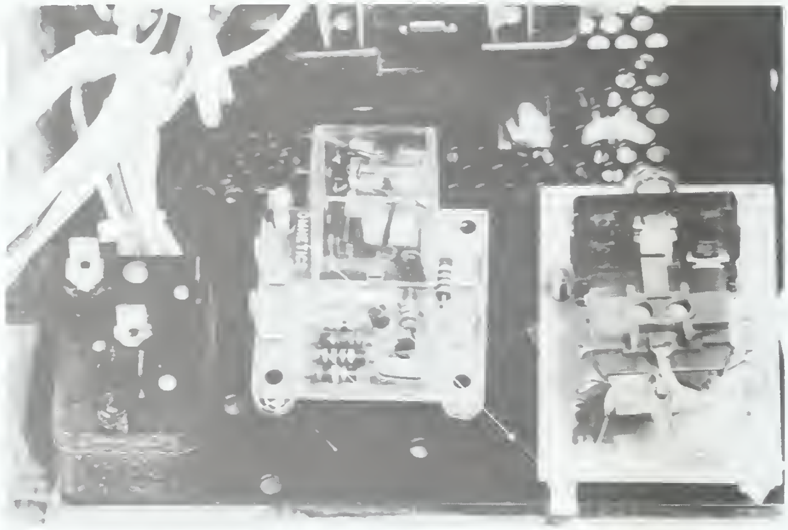


Figure 8-20 From left to right: Thermal holding relay, 10-second warm-up relay, and 60-second shut-down relay.

the *start-up, holding* and *shut-down* circuits are typical of many of the circuits used by various other manufacturers. Refer to Figure 8-21. A simplified sequence of operation is as follows.

The oven goes into the IDLE CONDITION when the door is either opened from the closed position or closed from the open position. When the door is opened or closed the contacts of the AUTOMATIC START SWITCH momentarily connect and provide a current path to energize the coil of the HOLDING RELAY (RL1). Then RL1 contacts (7) and (9) close to provide a circuit which keeps the coil of the HOLDING RELAY energized (this is referred to as a *holding circuit*). To complete the circuit, a current path is provided to the other side of the HOLDING RELAY through the normally closed contacts, (3) and (5), of the SHUT-OFF RELAY. At this point, the OVEN LAMP illuminates, the BLOWER MOTORS begin to rotate, and 120 volts AC is supplied to the HEATER (or filament) TRANSFORMER. The HEATER TRANSFORMER then supplies 3.2 volts AC to the *heater* (or *filament*) of the MAGNETRON TUBE. Thus the oven is in the IDLE MODE and ready for the execution of the cook cycle.

With the door closed, the PRIMARY and SECONDARY INTERLOCK SWITCHES are in the positions shown. Depressing one of the TIMER PUSH BUTTONS at this point will initiate the COOK CYCLE via the following sequence of operation: Pushing BUTTON #1, for example, actuates PUSH BUTTON SWITCH BANK 2 (timer contacts 2C, 2b, and 2a). This causes the COM and NO contacts of PUSH BUTTON SWITCH 2C to close, thus providing a current path to the coils of SELECT RELAYS 1 and 2. SELECT RELAY 1 energizes and actuates its contacts (17) and (16), which close to provide 14 volts DC to IC1. (The 14 VDC circuit will be explained in a succeeding paragraph.) Consequently, IC1 energizes the SOLENOID RELEASE RELAY (RL2), the contacts of which (11 and 14) close to complete a current path from the closed SELECT RELAY 2 contacts (18 and 19), and through the closed contacts (COM AND NO) of PRIMARY INTERLOCK SWITCH 1, to the COOK RELAY and the STIRRER MOTOR. The STIRRER MOTOR begins rotating and the COOK RELAY actuates its contacts, (6) to (8) and (12) to (10), which close and provide a current path to the HIGH-VOLTAGE TRANSFORMERS and the COOKING INDICATOR LAMP. Thus the oven is in the COOK CYCLE.

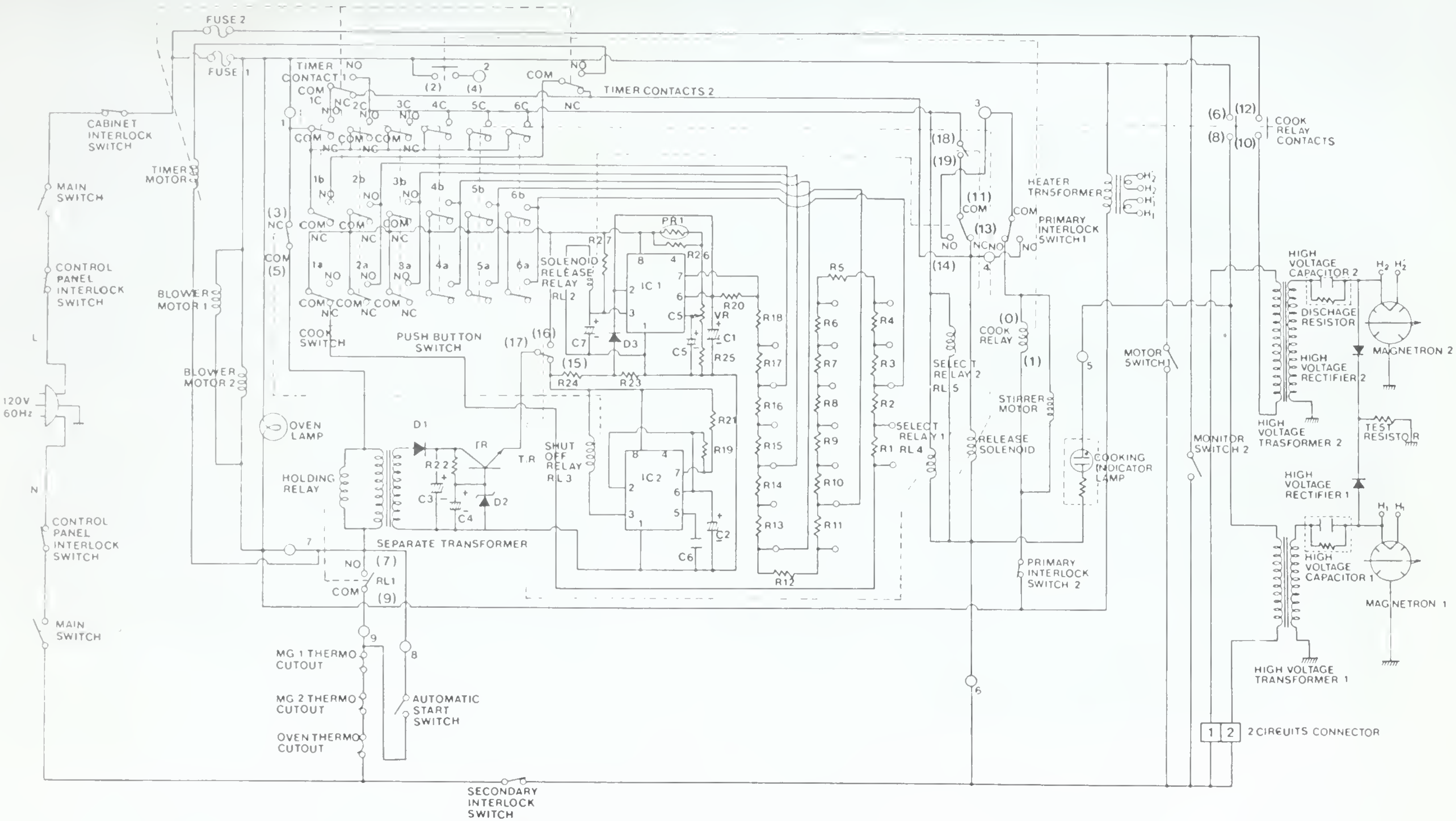


Figure 8-21 Start-up, holding, timing, and shut-down circuit.

The timing of the COOK CYCLE is determined by the charge time of CAPACITOR C1. With BUTTON #1 depressed, the COM and NO contacts of PUSH BUTTON SWITCH 2b (and 2a) are closed. The resulting 14-volt charge path is from the closed SELECT RELAY 1 contacts (17 to 16), up through PB SWITCH 2b, through RESISTORS R17, R18, and R20, to C1. When C1 charges to about 10 volts (the charge time depends on the number of resistors in the timing circuit), the effect causes IC1 to de-energize the coil of the SOLENOID RELEASE RELAY, the contacts of which (11 to 13), close to complete the circuit which activates the TIMER RELEASE SOLENOID. The RELEASE SOLENOID functions to release PUSHBUTTON #1, so contacts 2a, 2b, and 2C are subsequently opened. The circuit to the COOK RELAY and STIRRER MOTOR no longer exists so these components deactivate and the COOK CYCLE terminates. Also, the circuit to SELECT RELAY 1 is opened, so its contacts, (17) to (15), close to once again provide the 14 volts DC to INTEGRATED CIRCUIT IC2 and a charge path to CAPACITOR C2. Thus the oven reverts back to the IDLE MODE.

The oven will remain in the *idle mode* for about 30 seconds. IF, during that time, a cook cycle is not initiated and the door remains in either the closed position or the open position, the unit automatically shuts down. The AUTOMATIC SHUT-DOWN process occurs through the operation of the INTEGRATED CIRCUIT designated IC2.

The operation of the AUTOMATIC SHUT-DOWN circuit is as follows: The 120 volts AC applied to the primary winding of the SEPARATE (or low-voltage) TRANSFORMER is stepped down so that about 13 volts AC is present on the secondary winding. The 13 volts AC is then converted (or rectified) into 18 volts DC by the DIODE (D1) and the CAPACITOR (C3). The 18 volts DC is further processed by the operation of the TRANSISTOR (TR), the ZENER DIODE (D2), the RESISTOR (R22), and the CAPACITOR (C4). These components regulate or stabilize the 18 volts DC, and, in the process, convert the 18 volts to 14 volts DC. The 14 volts DC is applied to pin 8 of IC2 and to the CAPACITOR (C2) through the closed SELECT RELAY contacts, (17) and (15). The voltage across C2 gradually increases as it charges through RESISTORS R19 and R21. After about 30 seconds, the charge on C2 reaches 10 volts. Upon reaching a charge of 10 volts, C2 then discharges. The discharge path of C2 is through IC2, from pin 6 to pin 3. The subsequent output from Pin 3 of IC2 energizes the coil of the SHUT-OFF RELAY. The SHUT-OFF RELAY operates to open its contacts (3) and (5), thus discontinuing the circuit to the coil of the HOLDING RELAY. As a result, the HOLDING RELAY deactivates, thereby opening its contacts (7) and (9), which then discontinues the circuits to (and thus de-energizes) the SEPARATE TRANSFORMER, the OVEN LAMP, the BLOWER MOTORS, and the HEATER TRANSFORMER. The oven therefore reverts to the STAND-BY MODE.

EXAMPLE 8.2: Start-up, Holding, and Shut-down Operation

A second example is that used by many commercial ovens made by *Litton*. These units, mostly among the 80 series of commercial ovens, use a *load resistor* (Fig. 8-22) in conjunction with the holding relay, as illustrated in the simplified schematic of Figure 8-23A. The description of operation is as follows: With the oven in the standby condition, the door is opened which allows door interlock switch (S1) to "click" over to its NC (normally closed) contact. Power is applied through S1, through the *load resistor* (R1), energizing the holding relay (K1). The contacts of K1 then close, bypassing S1. Consequently, when the door is closed again, power will continue to be applied to the holding relay and to pins 8 and 9 of the electronic controller—*holding* the oven in the "ready" mode.

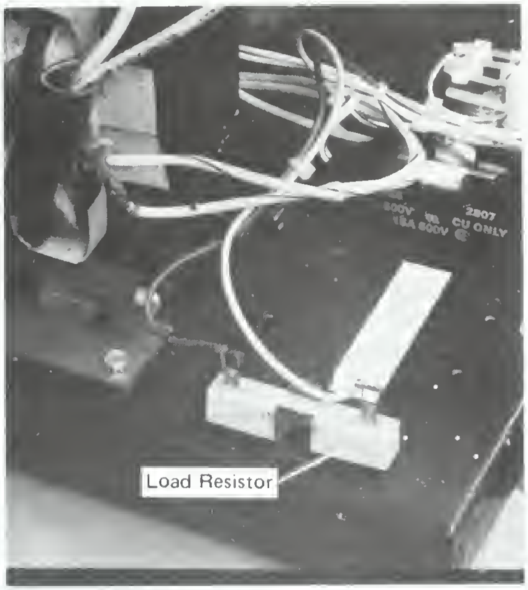


Figure 8-22 Load resistor.

After 60 seconds, or so, in the ready mode (with no further operations initiated by the user), the controller then places a short circuit between pins 8 and 3 by turning "on" triac D1 (Fig. 8-23B). This effectively shunts K1 out of the circuit, so its contacts open and the oven reverts to the standby mode.

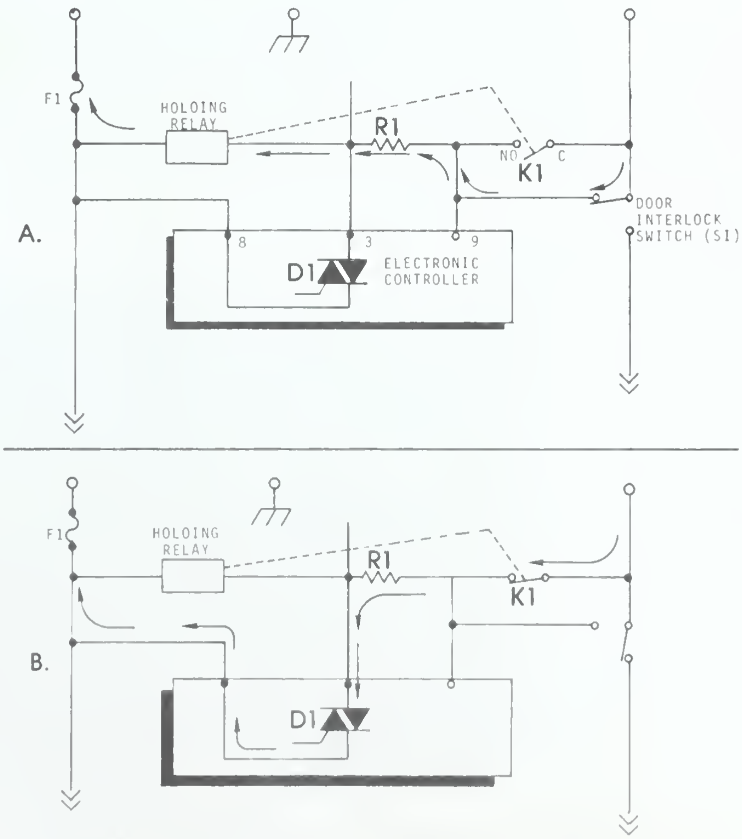


Figure 8-23 Simplified schematic of a load resistor circuit.

8.10 THE COOK RELAY

The cook relay is an electro-mechanical switch that is energized by the control circuitry. Figure 8-24 shows some typical cook relays that are used in microwave ovens. The contacts of the cook relay, when closed, provide the current path to the primary winding of the high-voltage transformer, which in turn develops the high voltage necessary for magnetron operation. Due to the high current draw of the transformer, a *surge resistor* is usually inserted between the contacts to act as a current limiter during the initial current surge. When the relay contacts close the surge resistor is bypassed.

8.11 OUTPUT POWER CONTROL

In conventional ovens a thermostat is set for the desired temperature and the heating element will cycle on and off to maintain that temperature. Microwave ovens use a similar type of system to control the RF output power.

The most common method of regulating the energy output is by the use of a *duty control circuit*. This is an arrangement by which the magnetron duty cycle (or "on" time) is effectively interrupted at regular intervals. Cycling the microwave energy on and off at this controlled rate results in an equalizing or heat transfer within the food being cooked. Perhaps the most frequently used method of accomplishing this is a means by which the voltage supply or *primary* voltage to the high-voltage transformer is cycled on and off in a controlled fashion. This *primary-side duty control* determines the on-off time of the magnetron, thus varying the average output power of the oven. The second most common technique is to control the on-off time of the magnetron tube from the *secondary* or high-voltage side of the power transformer. This *secondary-side control* is done by means of a high-voltage switching device. Other methods involve various ways of raising or lowering the high voltage itself. For example, some older models use large high-wattage resistors in series with the high-voltage output, which lower the voltage potential to the magnetron when switched into the circuit. Others increase or decrease the overall capacitance in the voltage doubler circuit which correspondingly increases or

Figure 8-24 Typical cook relays.

decreases the high-voltage potential to the magnetron. This capacitive control is accomplished by electrically switching to either the high or the low value of a dual-rated capacitor.

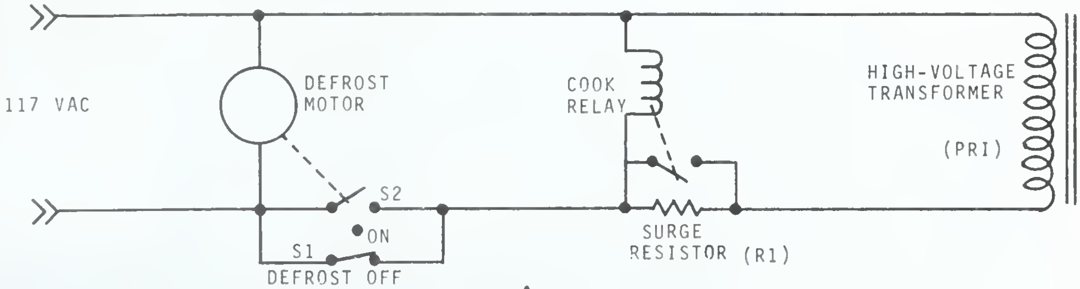
8.12 PRIMARY SIDE DUTY CONTROL

A basic method of controlling the primary voltage to the transformer is depicted in Figure 8-25, a simple defrost circuit (the defrost setting may also be referred to as "low"). When S1 is in its "defrost off" (A) position, the unit operates at 100% power. Setting S1 to the "defrost on" (B) position opens its contacts, effectively removing it from the circuit. The current path to the transformer must now rely on the contacts of S2 which are mechanically opened and closed by a cam that is attached to the motor shaft. The cam slowly rotates, closing S2 for about 20 seconds; then it opens S2 for about 40 seconds (the actual time base, or increments of time as determined by a complete rotation of the cam, varies with make and model). Thus, this circuit functions to complete, then interrupt, the circuit to the primary of the transformer in a controlled fashion.

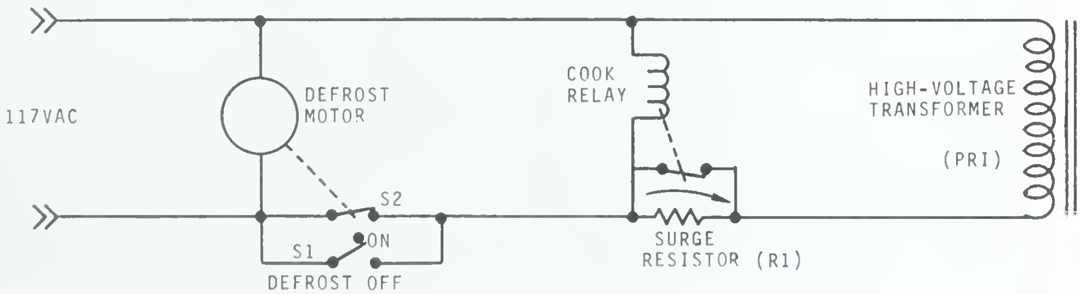
When voltage is initially applied to the high-voltage transformer, a brief high current surge can exist which would very quickly damage the cook-relay contacts, plus those of S1 or S2, depending which mode were selected. To prevent this arcing, or "welding" of the contacts, a surge resistor (R1) is placed in the circuit.

Surge resistors, typically from 3 to 10 ohms in value and rated at 10 or 20 watts, are placed in circuits where high-current switching must take place to protect

NOTE:
This schematic is generalized and simplified for illustrative purposes, it is not intended to precisely depict any one actual operating circuit.



A



B

Figure 8-25 Simple defrost circuit.

the contacts of the timer, relay, and other switches. Additionally, the surge resistor serves to protect the house circuit in that it prevents the undue opening of the breaker from a momentary surge.

During the first instant of applied voltage, the surge resistor causes a voltage drop which limits the initial surge of current to the transformer. In the defrost circuit example, the surge resistor is in series with the transformer for only as long as it takes for the cook relay to activate, which then removes the effect of the surge resistor from the circuit. It becomes apparent that a failure of the cook relay or its contacts would leave the surge resistor in the circuit. The surge resistor would be in the circuit for only a moment before it would overheat, burn, and physically crack open (Fig. 8-26), thereby opening the circuit almost as a fuse would. Indeed many designs use a surge resistor in the dual role of a current limiting device and a fuse.

Before returning to the defrost circuit, one other means of surge protection bears mentioning here. Figure 8-27 shows a design that uses a portion of the relay winding itself to momentarily impede the surge current.

With adequate surge protection, the defrost circuit components function as they should; the net result is a magnetron operating time of about 20 seconds out of every minute, or an average output of approximately one-third power. (Basic defrost cycles range from 33% to 43% of full power, depending on the model.) Defrost timing circuits are produced in several different ways depending on the make and model. Electro-mechanical defrost assemblies, such as the one pictured in Figure 8-28, consist of a motor, cam, and switch. In certain carousel models (equipped with a turntable or rotating tray), the defrost timer is geared in with the turntable motor. And, in still others, the cook timer mechanism actuates the defrost control through a system of gears (Fig. 8-29).

8.12.1 Mechanical Controllers

Figure 8-30 displays three common types of electro-mechanical controllers. A typical *mechanical controller* (also variously referred to as *percent timer, variable power control,* or *selector control*) provides infinite settings between "high" and "low". As shown by the disassembled controller in the center, the mechanism consists of a set of normally closed switches or contacts which are activated by a rotating cam. The cam is either asymmetrical in shape, or circular with a notch or

Figure 8-26 A burned surge resistor indicates defective relay contacts.

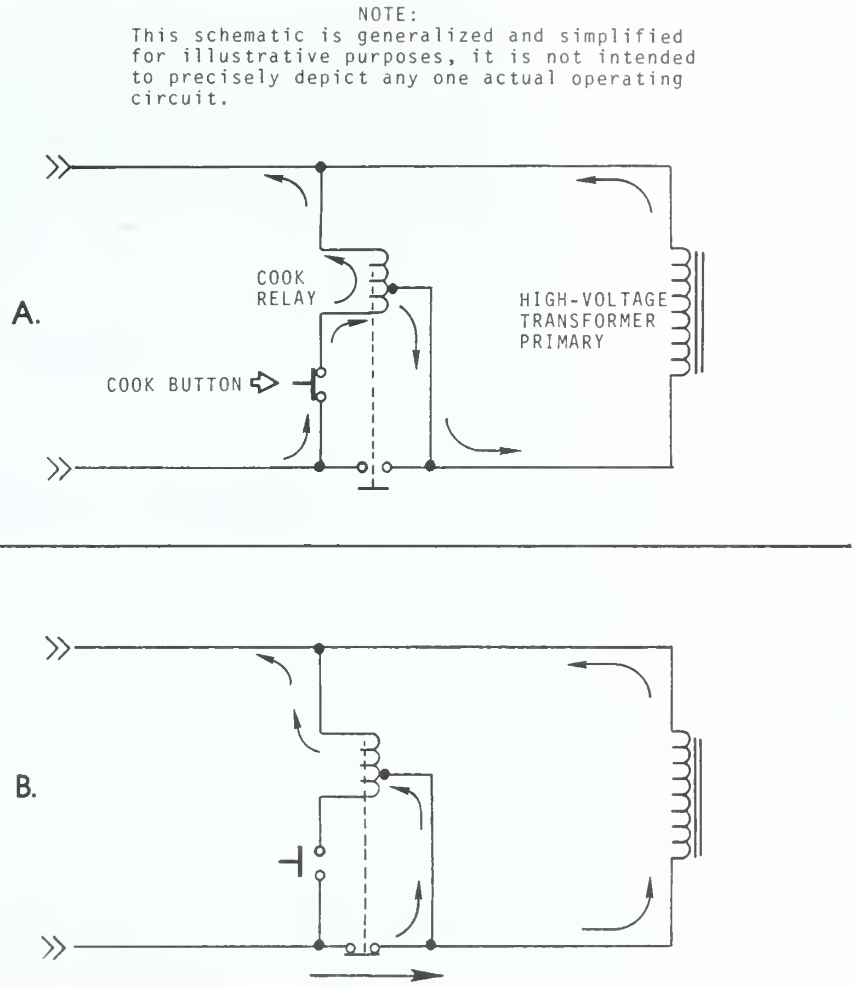


Figure 8-27 Relay coil providing surge protection.

Figure 8-28 Basic defrost timer.

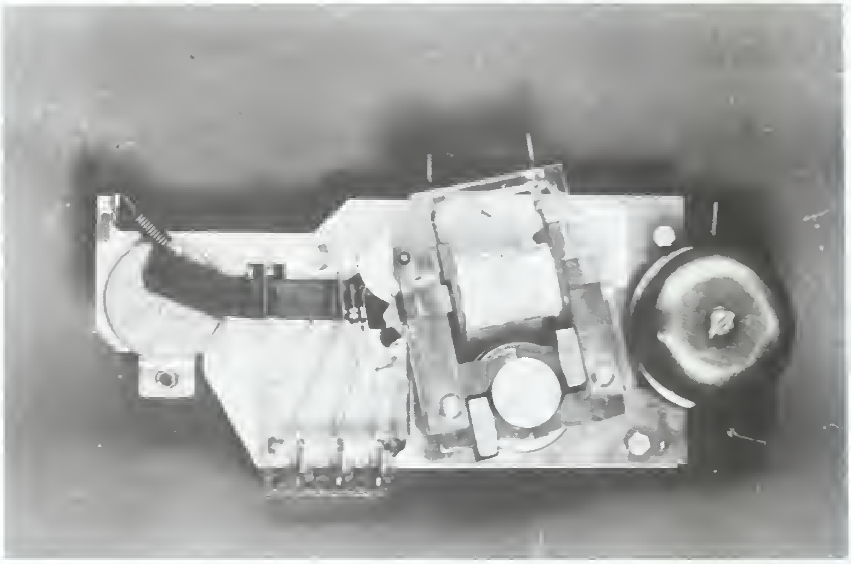


Figure 8-29 Defrost and cook timer assembly.

trigger formed on its perimeter. Figure 8-31 illustrates a representative schematic of a typical electro-mechanical controller. While the mechanics and the actual circuitry will vary, the basic principles of operation are the same. The circuit description is as follows: As the controller motor rotates, it drives an irregular-shaped cam which causes the contacts of S1 and S2 to open and allows them to close at different rates. The percentage of both open (off) and close (on) time is determined by the physical position of the rotating cam in relation to the contact actuators. This relative position changes with the selection of cooking power. When set on 100 percent output power, the cam completely bypasses the switch actuators allowing the switches to remain closed. The two switches, S1 and S2, are physically off-set to provide a sequenced action. During the cycling operation S1 closes first, temporarily inserting the surge resistor R1 into the circuit. This is followed immediately (about ½ second) by the closing of S2 which by-passes R1, removing it from the circuit and

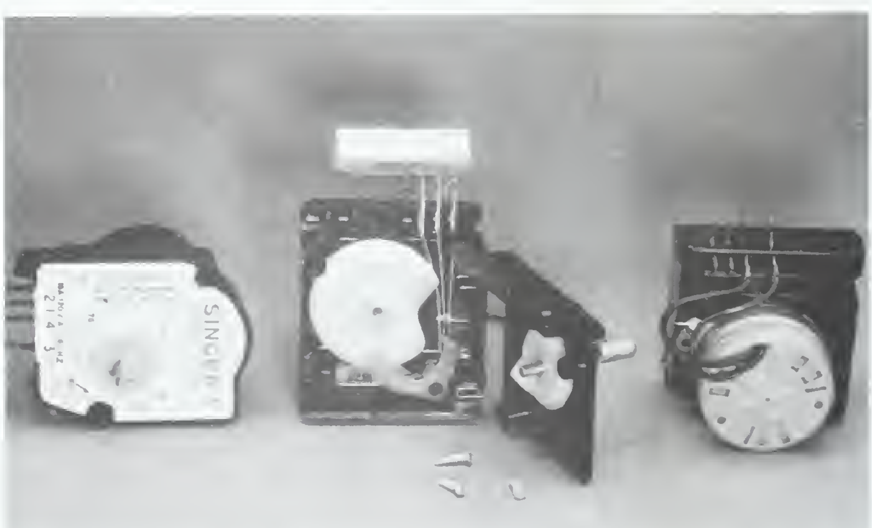


Figure 8-30 Typical electro-mechanical controllers.

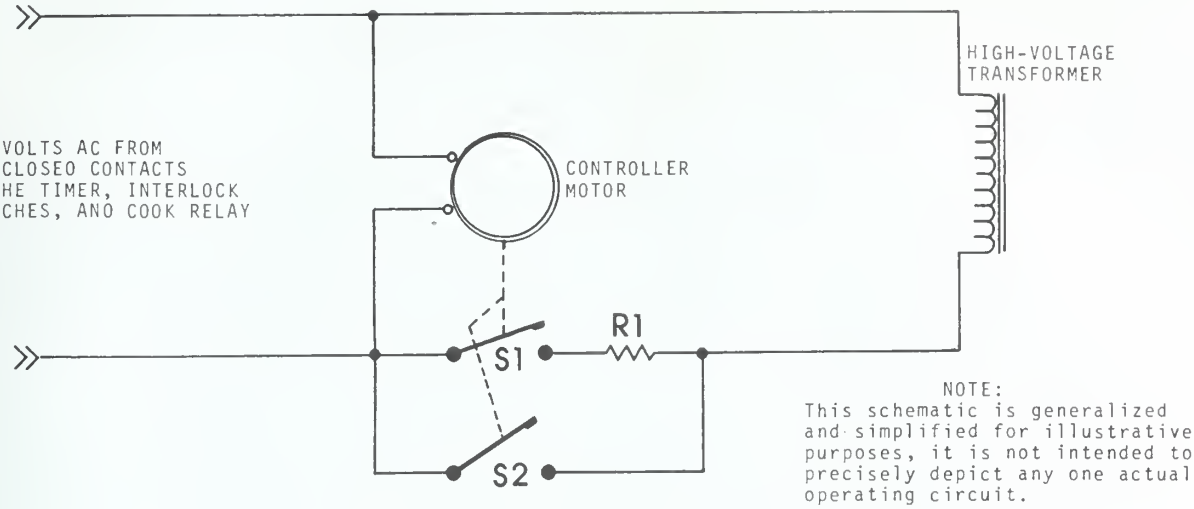


Figure 8-31 Representative electro-mechanical controller circuit.

allowing current to flow directly to the transformer which then energizes the magnetron. The surge resistor here serves the same purpose as described earlier.

The time base or time cycle of these controllers vary. A typical time base of 30 seconds would produce a magnetron "on" time of 15 seconds and an "off" time of 15 seconds if set at 50 percent power. As the chart in Figure 8-32 shows, any of the

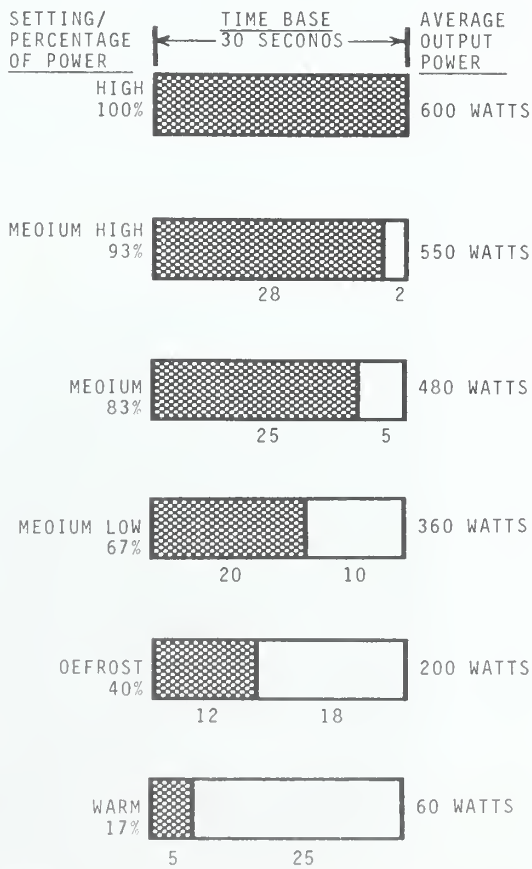


Figure 8-32 Duty cycle within a 30 second time base.

infinite output power settings between 100 percent and approximately 10 percent will change the "on-off" time relationship within the 30 second time base.

8.12.2 Solid State Controllers

Figure 8-33 presents types of the solid state controllers that are used in microwave ovens. Schematics of these units have not been readily available, and component identification is difficult, if not impossible, due to manufacturer's coding. Therefore, the subsequent description of operation is limited to that extent. These controllers serve the same purpose as their mechanical counterparts except that they use electronic switching and timing methods. Solid state components provide shorter and more frequent pulses of energy to give more precise cooking control. For example, a typical controller with a 1 second time base would vary the 120 volts input to the primary of the power transformer as shown in the chart in Figure 8-34A, the shaded area being the "on" time of the magnetron. The effect of a 12 second time base controller is shown in the chart of Figure 8-34B. Again, the shaded area shows the percent of "on" time within a 12 second time base. (The time period or time base during which the primary voltage input to the transformer is turned on and off varies with make and model.)

The following description of operation, using the controller with a 12 second time base, is somewhat sketchy, but should be sufficient to provide an overall idea of the basic principles of controller operation. This partially-deciphered controller circuit consists of a Linear Integrated Circuit (IC1) which integrates a timer and an oscillator, two silicone controlled rectifiers (SCR1 and SCR2) which are solid-state switches, a potentiometer or rotary type variable resistor (VR1), and associated support circuitry.

Refer to Figure 8-35. Attached to the potentiometer (VR1) is an on-off switch with its contacts S1 and S2. When the variable controller is set to the "high" position the switch contacts S1 and S2 close, as evidenced by an audible click. The current then flows from terminal 2 (VAC in) through R3, which drops the voltage to the appropriate *threshold* level to be applied to pin 6 of IC1. The threshold voltage, applied through the closed contacts S1 and S2 (as indicated by the solid arrow) to pin 6 of IC1 causes pin 3 of IC1 to produce a constant output to the dashed state switch Q1, which is probably a silicone switch used for phase control. Q1 alternately provides gate signals to SCR1 and SCR2. Since SCRs conduct only in one direction,

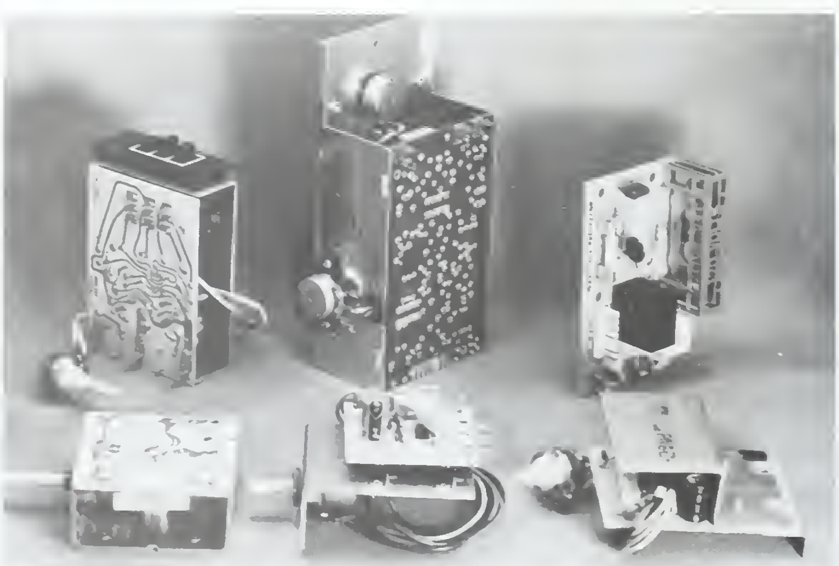


Figure 8-33 Solid state controllers.

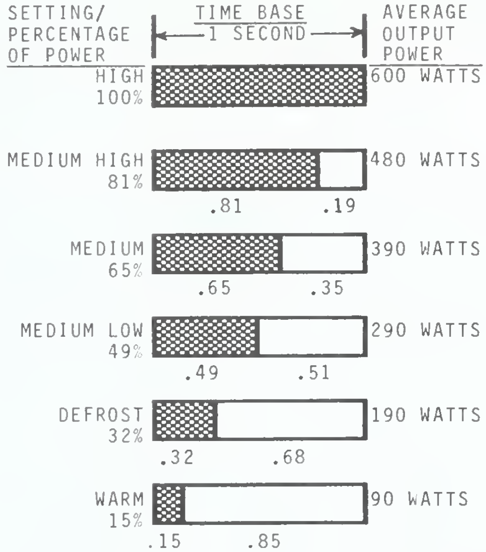


Figure 8-34A Duty cycle within a one second time base.

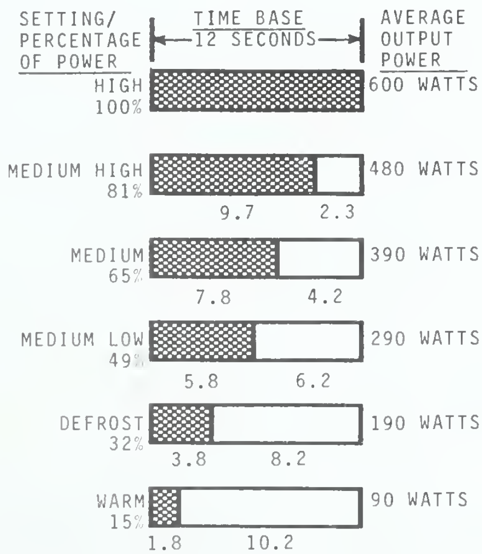


Figure 8-34B Duty cycle within a 12 second time base.

two SCRs are connected in an anti-parallel configuration. So, during the first half cycle of the applied VAC, Q1's gate signal turns on SCR1, which then conducts current from VAC IN (terminal 2) through itself to VAC OUT (terminal 1). Then, during the last half cycle of the applied VAC, Q1 "gates on" SCR2 which conducts in the same fashion as the now non-conducting SCR1. The resulting voltage at VAC OUT (terminal 1) is 120 volts of AC. In effect the 120 volts AC at VAC IN (terminal 2) is simply transferred to the output terminal, VAC OUT (1). Essentially then, closing the contacts S1 and S2 effectively bypasses the controlling circuitry, providing a constant 120 volts AC to the primary of the power transformer, so the oven cooks at full power.

If the oven controller is set to something less than full power, contacts S1 and S2 are opened. The voltage at pin 6 of IC1 is now determined by the resistance setting of VR1. The internal timer of IC1 establishes the time base of 12 seconds by sampling and referencing to the 60 cycles per second of the applied AC. Pin 7 of IC1 senses the resistance setting of VR1 by monitoring the resulting voltage drop across

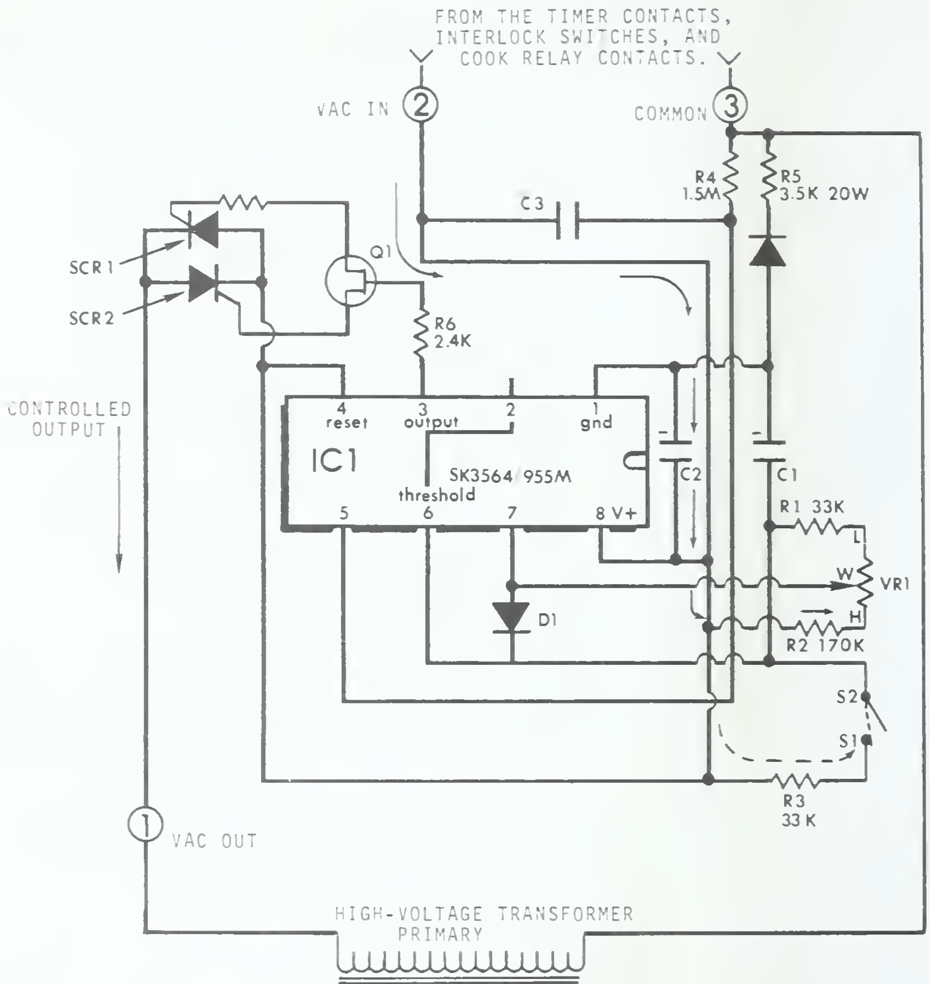


Figure 8-35 Approximation of a controller circuit.

point "H" to point "W" on VR1. A high resistance setting at point "W" will result in a lower voltage at pin 6. The voltage at pin 6, which is inversely proportional to the voltage at pin 7, is compared to the control (constant) voltage at pin 8. Basically, the result of this comparison determines the rate at which the output from pin 3 will vary Q1. Consequently, Q1 will turn the SCRs on and off at a corresponding rate. As a result, 120 VAC is delivered to the transformer in pulses that are percentages of the 12 second time base, the duration of each pulse being determined by the setting of VR1.

In the circuit just considered, it was assumed that the high voltage transformer used a common primary winding for both the filament and the high voltage secondary windings. Thus, in this case the magnetron filaments are heated only while primary voltage is applied to the transformer. Other systems, particularly those with a shorter time base, may use a separate filament transformer. In those cases, the magnetron filament temperature is maintained during the entire time that the oven is operational. In each case, and more so in controllers with shorter time bases, there is a noticeable dimming of the cavity light accompanied by a thumping or pulsing noise as alternating voltage inputs are applied to the transformer primary winding. Although this will give rise to concern on the part of new microwave oven owners, it is normal. In fact, to the observant technician, this provides audible and visual verification of proper controller operation. However, thumping or pulsing of

unusual severity could be an indication of controller-related trouble. *Sections 13.11* and *13.12* consider in greater detail the symptoms associated with controller-related problems and appropriate corrective measures.

8.13 TRIACS

The solid state counterpart to the cook relay is the *triac.* The term "triac" is actually a trademark of the *General Electric* company for a gate-controlled electronic switch. The triac was designed as an alternating-current switching device for power control, and so is emerging as the most common means of varying the transformer duty cycle in microwave ovens. The triac's ability to provide electronic switching where a low voltage and current controls a relatively larger voltage and current makes it well suited for this task. As Figure 8–36 shows, triacs used in microwave ovens come in a variety of shapes and sizes and, because of different operating characteristics, are not necessarily interchangeable. However, their basic operating principles are the same. Figure 8–37A through 8–37F shows the terminal arrangement and designations (unless otherwise marked) of typical triacs used in microwave ovens. Notice the *gate* terminal is always the smallest.

Just as you can flip a switch with your finger and turn on a light without coming into contact with the electricity, so too, the sensitive control circuitry can turn on the high-voltage transformer, simply by "flipping" on the triac and yet remain isolated from the associated high current and voltage. But instead of using a finger, the control panel uses a low-voltage signal called a *gate* voltage. Opening a gate valve in a water line allows water to pass through; applying a signal to the gate terminal of a triac opens its gate, so to speak, allowing current to flow through. Another gate signal closes the triac's gate and it "turns off" the current flow just as closing the gate valve stops the flow of water. The actual gate or trigger voltage used in different makes and models varies considerably and may be DC or AC coupled. A few examples are 0.5 to 0.75 volts AC in some *General Electric* and *Amana* models respectively, 2 to 3.5 volts in older *Magic Chef* models, 7 to 18 volts DC in older *Litton* models, 13 volts AC in newer *Littons,* 12 volts DC in some commercial *Amana* models, 20 to 28 volts AC in some Whirlpool models, and still higher voltages in others. For specific triac gate voltage information on any particular model, the respective service manual should be consulted.

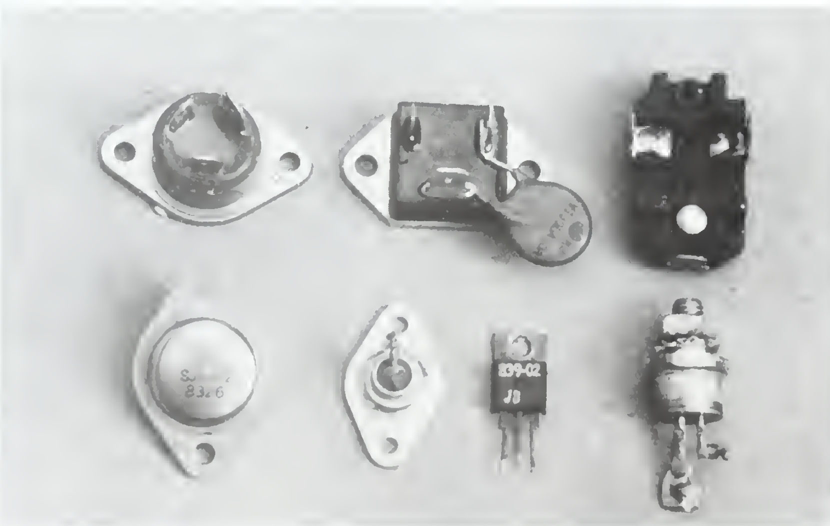


Figure 8-36 Triacs used in microwave ovens.

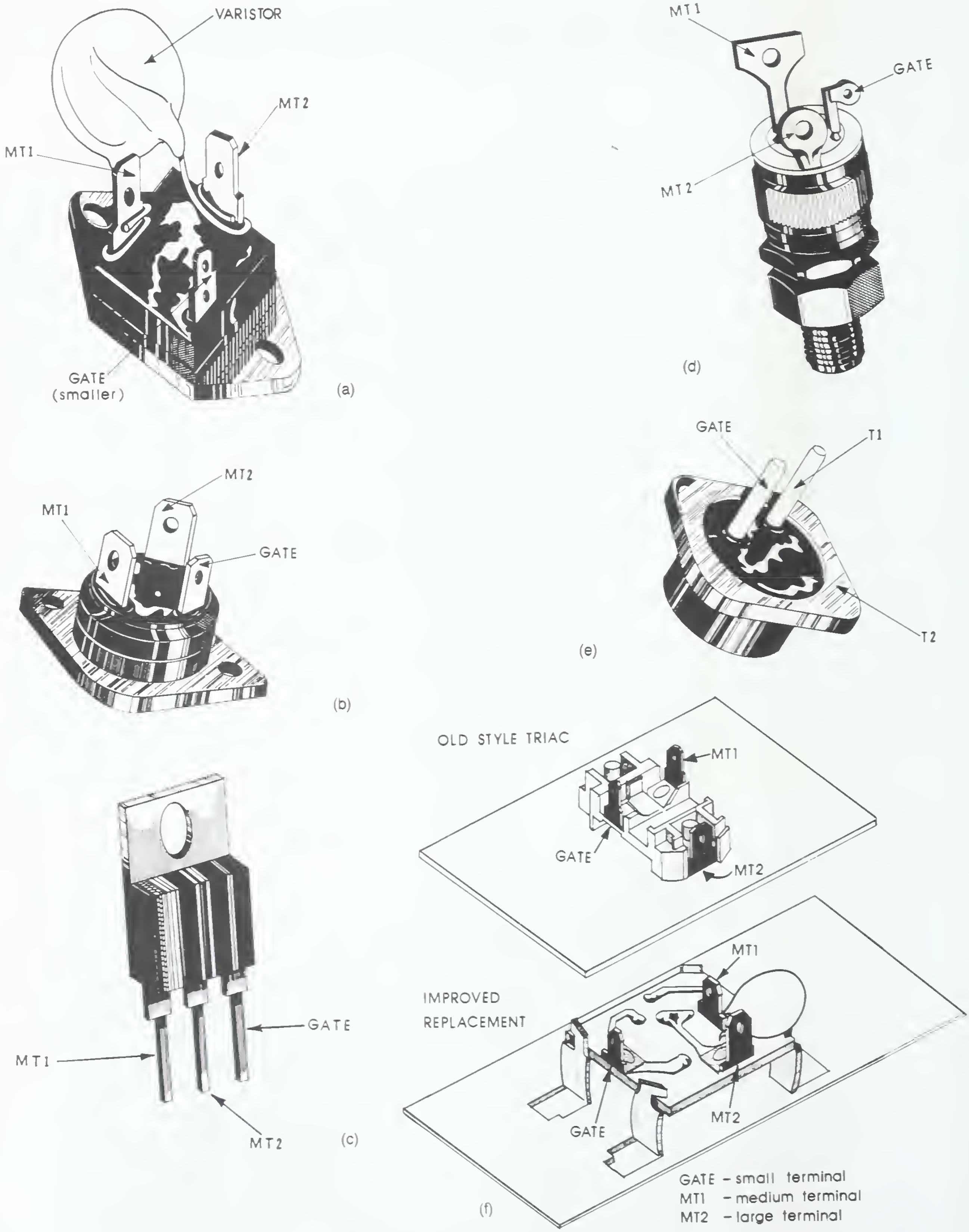


Figure 8-37 A through F Triac terminal identification. (Courtesy of Michael S. Wagner)

8.13.1 System Operation

The representative schematics of Figure 8-38 illustrate the typical operation of a triac controlled system. Notice that the schematic symbol for a triac resembles the two SCRs connected in the antiparallel configuration shown earlier in Figure 8-34. A triac *is* essentially two silicone rectifiers fabricated in an antiparallel arrangement with a common gate. To gain a better understanding of an entire operating system, the explanation to follow is of a typical triac-controlled circuit in the context of a schematic that includes all the associated components necessary for an actual working system. Unfamiliar components that are not explained at this time will be elaborated upon in subsequent chapters. Refer to Figure 8-38.

SCHEMATIC #1

With the oven plugged into a standard 115 VAC grounded outlet, voltage is applied through the 15 amp FUSE to the primary of the LOW-VOLTAGE TRANSFORMER which supplies the operating voltages to the control circuitry. The time-of-day clock operates and the CONTROL PANEL is ready to receive instructions.

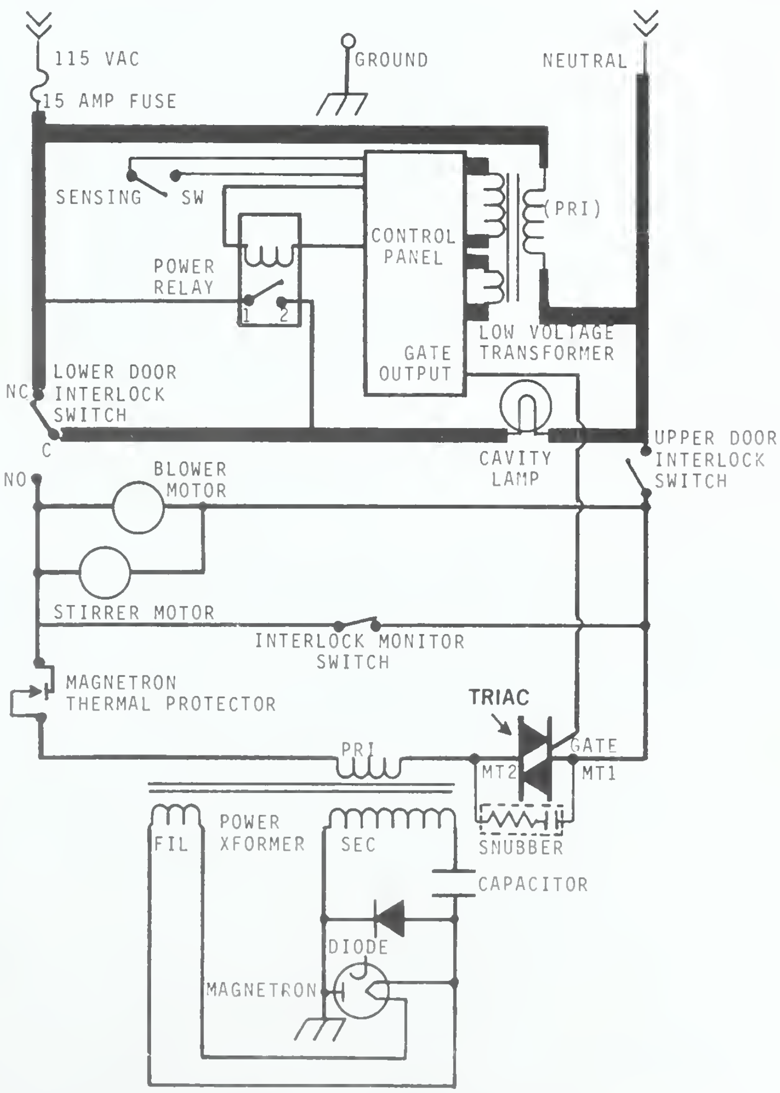


Figure 8-38A System operation.

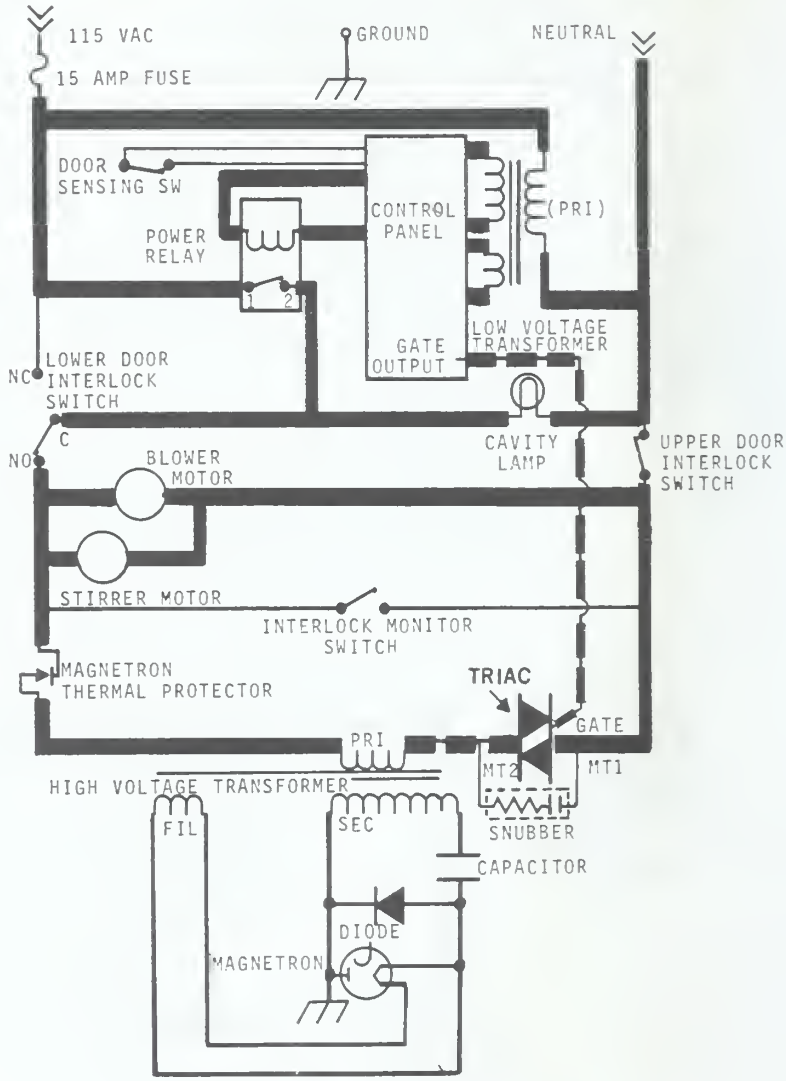


Figure 8-38B System operation.

The oven door is then opened and the CAVITY LIGHT illuminates with current supplied through the *normally closed* (NC) contacts of the LOWER DOOR INTERLOCK SWITCH.

SCHEMATIC #2

Food is placed in the oven, the door closed, and the CONTROL PANEL programmed for 10:00 (ten minutes) of cooking time at 80 percent of full power or "medium". When the "start" pad is pressed, the CONTROL PANEL activates the POWER RELAY which closes its contacts 1 to 2. Through the POWER RELAY'S closed contacts current is supplied to the CAVITY BULB and, through the [now closed, but] *normally open* (NO) contacts of the LOWER DOOR INTERLOCK SWITCH to the STIRRER MOTOR and BLOWER MOTOR. Voltage is also available, through the closed THERMAL PROTECTOR contacts, to one side of the POWER transformer's primary winding. In order for the oven to cook, there must be a complete circuit to both sides of the primary winding of the transformer. This is provided through the *normally open* [but now closed] contacts of the UPPER DOOR INTERLOCK SWITCH, and is controlled by the TRIAC. As the dashed

lines indicate, the gate voltage signals the TRIAC to turn on and off at a rate determined by the initial 80 percent power setting. The TRIAC, correspondingly, provides the needed complete circuit to the TRANSFORMER in a cyclic manner. The voltage is thus supplied to the high-voltage system in controlled cycles of specified durations resulting in an average overall output of about 80% of full power.

If the oven door were opened before the ten minute cook period elapses, both the UPPER and LOWER INTERLOCK SWITCHES would immediately open the circuit to the transformer, causing the high voltage and thus the RF energy output to cease. The control panel also senses the door opening through the DOOR-SENSING SWITCH and suspends the countdown process, deactivates the POWER RELAY, and discontinues any further gate signals to the TRIAC. Closing the oven door and pressing the "start" pad resumes the cooking process and the timer countdown. When the timer reaches zero it terminates the gate signals to the TRIAC, de-energizes the POWER RELAY and signals its finish with several "beeps" or a tone.

8.13.2 Additional Triac Information

Not discussed here, are systems where triacs are used to control convection heating or browner elements. These triacs work in the same manner as, and in some cases are interchangeable with, the transformer triac.

Associated with the triac in some cases is a *snubber, varistor* or some other sort of transient voltage suppressor. A snubber is basically a resistor and capacitor network (RC network) that absorbs any spikes that might occur when the transformer powers up or shuts down. A varistor is a voltage sensitive resistor. A voltage spike or surge will cause the varistor's resistance to drop so that it *shunts* the spike (or provides a by-pass) around sensitive components. (See *Section 9.8* for a more detailed discussion of voltage protection devices.)

Many models use *triac modules* or *auxiliary modules*. These modules, examples of which are pictured in Figure 8-39, contain the triac as well as the voltage suppression, protection, and other support circuitry.

An inherent disadvantage in primary-side duty control is the high stress factor placed on the secondary or high-voltage components, due to transient currents caused by the triac or controller interruption of the primary supply. This stress could

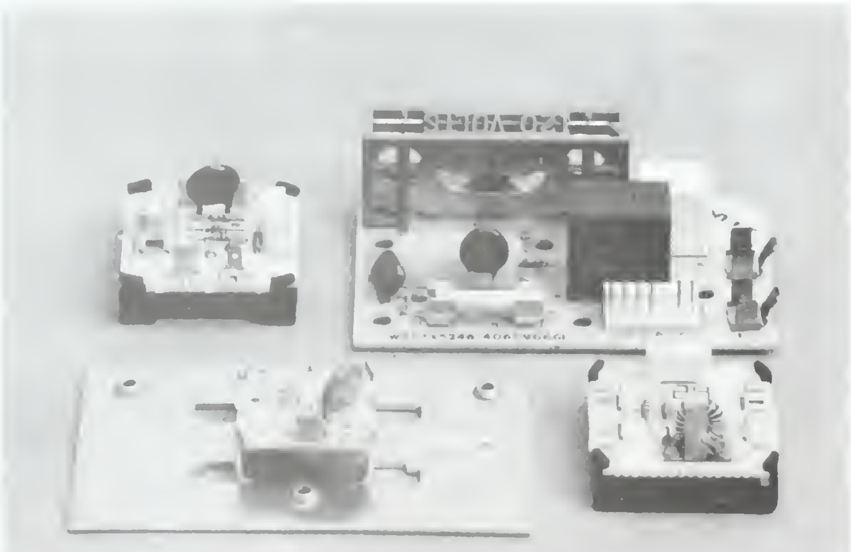


Figure 8-39 Common triac modules.

result in a shortened life of an affected component, although new system designs and suppression circuitry make this unlikely.

The triacs discussed thus far are physically external of the control circuitry and can be tested and replaced as such. In many cases, however, the triac is part of the internal circuitry of the control panel and, unless parts and schematic information are available in those cases, must be diagnosed and replaced as an entire control unit.

Triac testing procedures, failures with associated symptoms and related consequences, as well as proper corrective measures, are discussed in *Sections 13.12 and 13.13.*

8.14 SECONDARY (HIGH-VOLTAGE) SIDE DUTY CONTROL

As opposed to primary duty control, this circuit controls the on-off time of the magnetron on the *secondary,* or *high-voltage side.* This is accomplished with a high-voltage switching device, usually a reed relay (Fig. 8-40). These relays are referred to as either a variable power switch or *high-voltage relay,* and are controlled by a low-voltage signal from the control panel. The high-voltage circuit in Figure 8-41 demonstrates a common way in which the high-voltage relay is connected into the secondary circuit. When the contacts of the relay are opened, the high-voltage supply is disconnected from the magnetron tube.

When something less than full power is selected, the high-voltage relay is activated intermittently by signals from the variable power control section of the control panel. Just as with primary side control, these relay drive signals, typically about 25 volts DC, control the opening and closing of the relay contacts within a specific time base. It would seem as though opening or closing a set of contacts with upwards of 3000 to 4000 volts applied would result in extensive arcing and damage, if not destruction, to the contacts, and indeed it would if that were the case. The fact is, there is no voltage being applied during the time the relay is opening or closing its contacts. This is accomplished by a phase control circuit.

Figure 8-40 High-voltage relays.

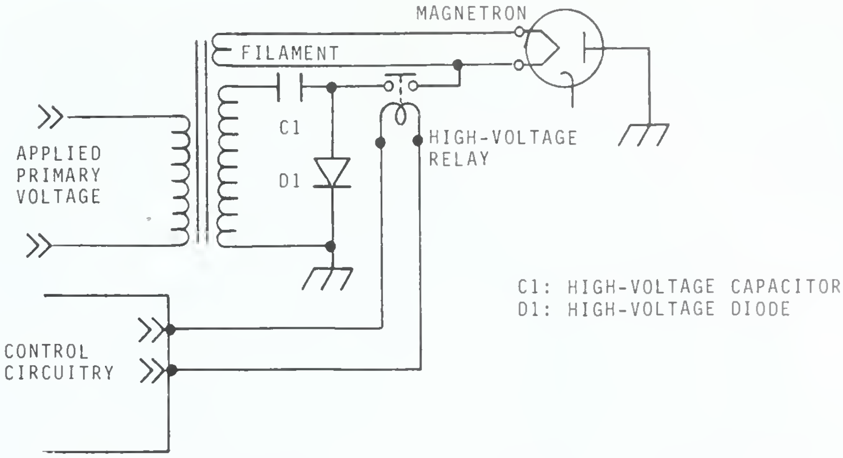


Figure 8-41 Secondary circuit with a high-voltage switching device.

8.15 PHASE CONTROL CIRCUIT

In conjunction with the variable power circuitry, the phase control circuit functions to control the open-close timing of the high-voltage switching device. This prevents damaging high-voltage arcing as well as any possible radio and TV interference that may be generated as the contacts open or close. Recall from the description of the high-voltage system in *Chapter Seven* that the high voltage is applied to the magnetron only during the *negative half* of the AC cycle. There is no voltage developed across the contacts of the high-voltage switch during the *positive* half cycle. The basic idea of the phase control circuit, then, is to see to it that the switching takes place only when there is *no* voltage potential present; that is during the positive half of the applied AC line voltage.

A typical secondary (high-voltage) side power control system consists of a phase control circuit, a multivibrator circuit (which is also used in the development of triac gate voltages), and the high-voltage switching circuit. A multivibrator is basically two transistor circuits arranged with regenerative feedback. In other words, one transistor is conducting while the other one is off. A signal must be applied to change this condition. After a period of time, determined by the internal resistances and capacitances (in the following example, the setting of VR1), the circuit returns to its original condition where it remains until the next signal is applied. Advanced technology in large-scale integration has made it possible to incorporate all these circuits as well as many others into one integrated-circuit chip or microprocessor. A representative block diagram of these common circuits is shown in Figure 8-42.

In the following basic description of operation of a phase control circuit (refer to Fig. 8-42), it will be assumed that the variable power level (VR1) is set to about 50 percent or "medium". When the start button is pressed a sample of the AC line voltage (approximately 18 VAC) is coupled into the phase control circuit. Only the positive portion of the input gets through diode D1. This results in the waveforms at point "A" which correspond to the positive half cycle of the line voltage frequency. Transistor Q1 conducts only during this positive half cycle and this produces the "trigger" waveforms at point "B". The multivibrator circuit controls the amount of time that the high-voltage relay remains either "on" or "off", and the circuit's output is synchronized to the positive half cycle of the line voltage frequency by these "triggers" at point "B". The ratio of "on" to "off" time, within a specific time base, is determined by the operator-set position of VR1, which is a variable resistor controlled from the front panel of the unit. Like Q1, Q2 conducts only during the

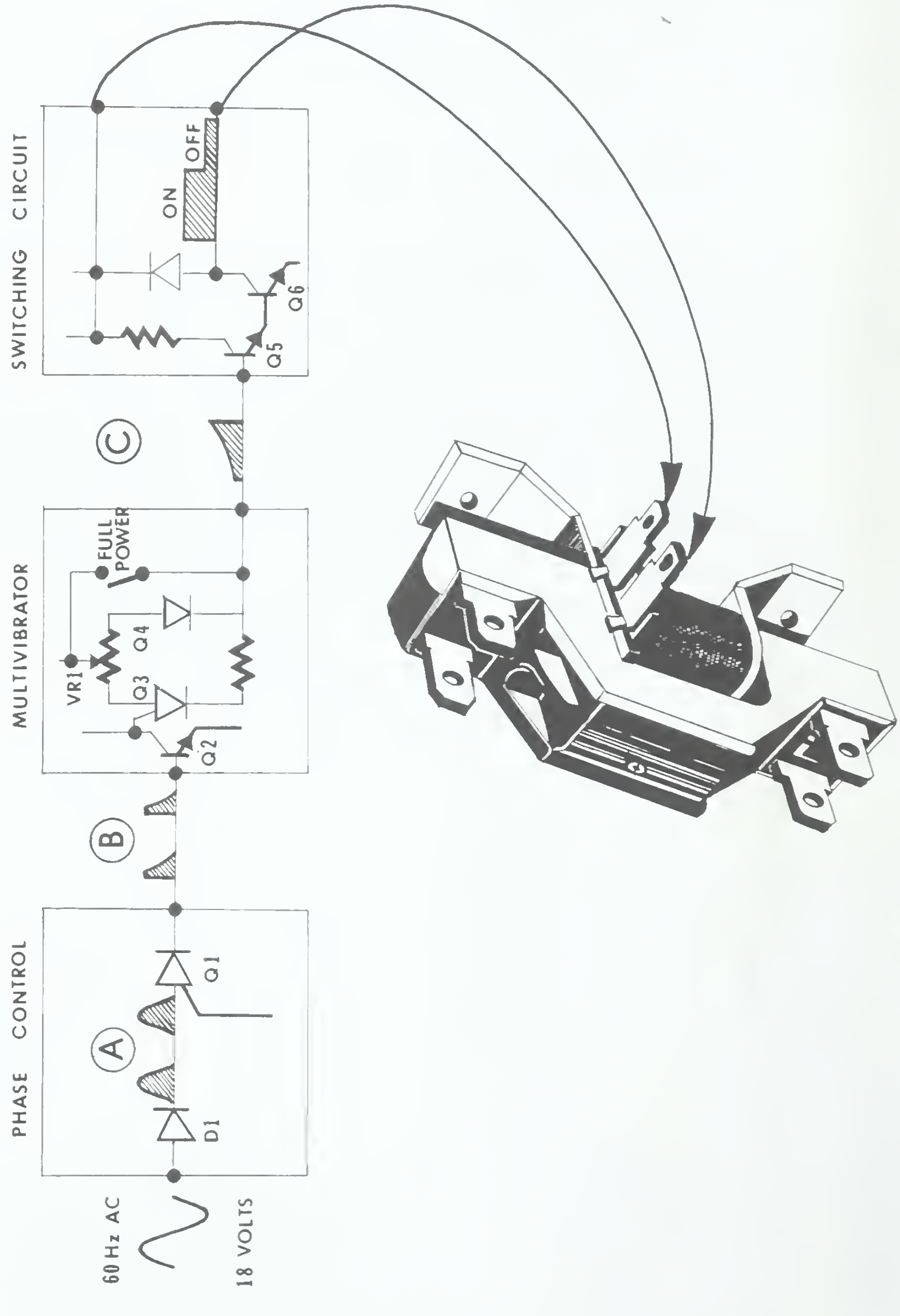


Figure 8-42 Block diagram of a common phase-control circuit. (Courtesy of Michael S. Wagner)

positive half cycle. Therefore, the multivibrator circuit produces an output only during the positive half cycle—when there is no high voltage present at the relay contacts. When Q2 conducts, the multivibrator shapes an appropriately phased output waveform (point "C") that will establish the duration of the "on" and "off" times of the high-voltage relay. If full power had been selected, the "full power switch", which is mechanically connected to VR1, would close and thus cause the multivibrator to produce a continuous output, although it would only begin or end on a positive half cycle. The "medium" setting, however, balances the multivibrator circuit and its output is applied to the switching circuit. As the leading edge of the waveform at point "C" is felt at its base, Q5 begins to conduct. This causes Q6 to conduct, providing 24 volts DC to the coil of the high-voltage relay, thereby connecting the high-voltage circuit to the magnetron. Thus, with high voltage applied, the magnetron begins oscillating and producing an RF output. Q5 conducts only for the duration of the pulse at its base (in this case for 50 percent of the time cycle). As the signal reaches zero, Q5 stops conducting and the switching circuit interrupts the 24 volts to the relay coil for the remaining 50% of the cycle. The high-voltage circuit to the magnetron is then interrupted, thus the tube ceases oscillation until the next cycle. The result is an effective output of approximately 50 percent of full power.

The overall effect on the output power being the same, the argued advantage in secondary control is less stress to components in the high-voltage system. This is because the high-voltage relay performs its switching when there is no high voltage being applied, thus no damaging transient currents are generated. However, this advantage may be outweighed by the inevitable problems resulting from the precarious electrical proximity of low-voltage signals and high-voltage circuits. Even though highly insulated, a high-voltage relay can break down internally and mete out quite a "blow" to the sensitive control circuitry.

8.16 ADVANCED SYSTEMS

In most cases a setting of "high" or full power will cause the relay contacts to remain closed throughout the selected cook time. However, even at a setting of "high", some models will monitor the magnetron output by means of comparison circuits in the microprocessor control section. Basically, the magnetron *plate current* is monitored through a power-sense *loop* in the high-voltage transformer. Then, through solid-state control circuits, the amplitude of the plate current is compared to that of the input line voltage. Based on the results of the comparison, the control circuitry increases, decreases, or maintains the percentage of magnetron "on" time, thus adjusting the RF output power accordingly. The purpose of this feature is to achieve and maintain an RF output power level that remains consistent despite fluctuations in the available line voltage. At full power an output of at least 600 watts, and no more than about 700 watts, is generally thought to be best for home use applications. The energy output of all microwave ovens is affected in the same way by line voltage: The higher the line voltage, the higher the energy output. If, for example, the input (line) voltage increased from 110 to 127 VAC, this could cause an energy output higher than the optimum 700 watts. If so, the control circuitry would sense this and reduce the magnetron's "on" time so that the effective output power remains the same. Voltage-compensating circuits, which may also be used in triac controlled systems, are of particular importance in full-featured units with extensive menus (including when to stir, when to cover, and so on) programmed right into the control panel microprocessor. Based on the input you supply as regards the kind of food, weight or amount, and how you want it cooked, the computer calculates these factors. It then assigns a corresponding energy output level which it relies upon to

produce satisfactory results. The output stabilizing circuits make this a remarkably effective system.

Another effective feature made possible by advanced technology is a defrost system that gradually decreases the energy output as the food thaws. When food is frozen solid a higher amount of microwave energy (about 80%) is used to break down the ice crystals. If the power remained at the higher level the food would begin to cook on the outer edges while the center was yet frozen. Instead, the magnetron's "on" time is automatically reduced to a lower power level (about 60%) for a time, and then reduced again. The duration of each power level is a percentage of the total defrost time selected. As the defrosting nears completion, the power level has been reduced to about 20 percent of full power so the product has been defrosted quickly, evenly, and with little or no cooking around the outer edges.

8.17 SECONDARY CONTROL BY VARYING THE HIGH-VOLTAGE POTENTIAL

A final means of varying the output power of a microwave oven is a system that changes the actual amplitude of the high voltage. This type of system is effective, but the power control is limited to no more than three settings, usually "high", "medium", and "low". Basically, the amplitude of the high voltage is lowered for lower power settings. This is accomplished in two ways:

(1) A dual-rated high-voltage capacitor (Fig. 8-43) in the high-voltage circuit. A dual-rated capacitor is two capacitors encased and suitably connected within the same housing. Figure 8-44 illustrates a typical circuit using a dual-rated capacitor. The description of operation is as follows: When the mechanical *"select switch"* is closed both capacitors are charged by the secondary voltage from the transformer during the positive half cycle. During the negative half cycle the stored voltages of both capacitors are combined with the transformer's secondary voltage and applied to the magnetron, so the magnetron oscillates at full power.

Figure 8-43 Dual-rated capacitor.

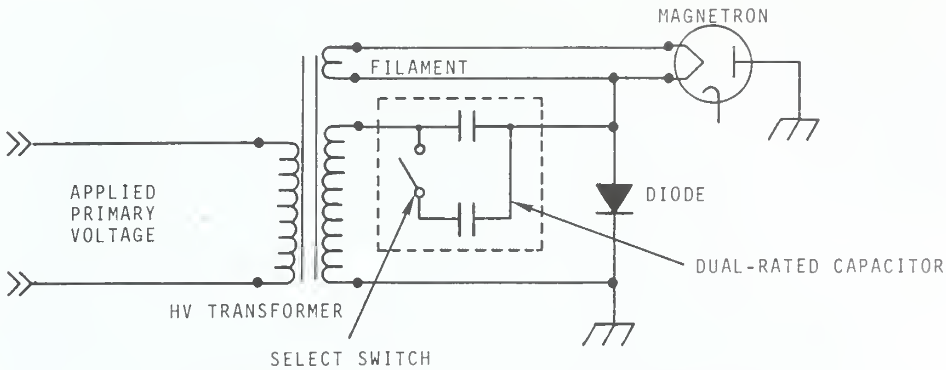


Figure 8-44 Dual capacitor in a high-voltage circuit.

Selecting the "low" setting opens the switch so that only one capacitor is charged by the secondary voltage during the positive half cycle. Therefore, the charge of only one capacitor is combined with the transformer voltage during the negative half cycle. Thus a lower voltage is applied to the magnetron resulting lower output power.

(2) Although the use of **large wire-wound power resistors** to drop the voltage to the magnetron is now somewhat obsolete, the circuit merits brief consideration since many of these ovens are still in operation. Depending on the model, the power resistors may either be two separate resistors, or one large resistor with a center tap as pictured in Figure 8-45.

The schematic in Figure 8-46 illustrates the operation of a typical voltage dropping network. The *"power select switch"* provides three choices: "high", "medium", and "low". The "low" setting opens contacts 3 to 4 and closes contacts 1 to 2. This puts the 1200 ohm resistor in series with the diode. During the positive half cycle when the capacitor is charging through the diode, a portion of the available secondary voltage will be used up (or dropped) across the resistor, so less voltage will be stored by the capacitor. During the negative half cycle, less voltage is available to be combined with the secondary voltage, resulting in a reduced voltage potential being applied to the magnetron, thus less power. A selection of "medium" opens contacts 1 to 2 and closes contacts 3 to 4. This lowers the resistance to 750 ohms, resulting in less of a voltage drop and a higher output. When on the "high" selection,

Figure 8-45 Center-tapped power resistor.

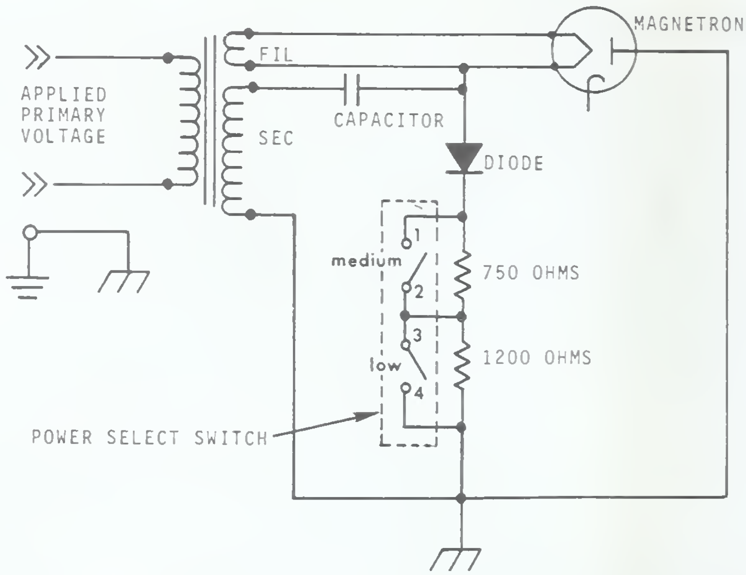


Figure 8-46 Power resistor in a high-voltage circuit.

both resistors are by-passed because both switches are closed. The resistors, therefore, have no effect on the circuit, so the full voltage potential is developed and applied to the magnetron tube thus producing the maximum power output.

8.18 THE PROBE

Seconds can be critical when cooking with a microwave oven. Deciding on just the right amount of cooking time for the best results becomes an art, if not guess work. (*Appendix II* will be of help in this regard.) Cooking by temperature control electrically eliminates the timer, and practically the guess work, by monitoring the relative temperature rise within the food with a *temperature probe.* When the user-selected temperature is reached, the sensor probe informs the control circuitry to either hold the food at a specified temperature or terminate the cooking process (options vary with make and model).

Figure 8-47 shows a probe assembly with its waterproof shaft, micro-

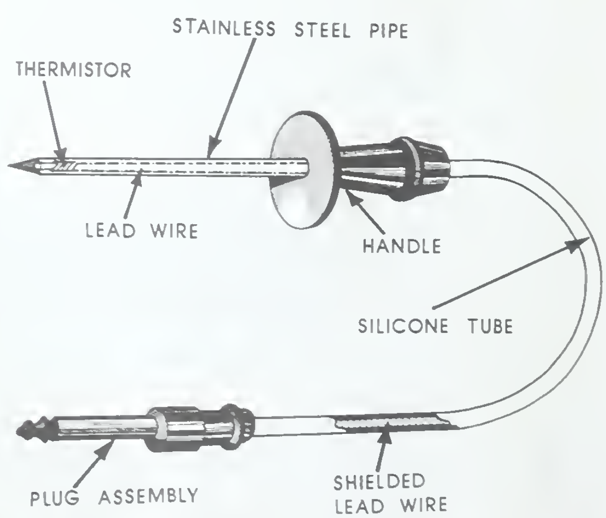


Figure 8-47 Probe assembly. (Courtesy of Michael S. Wagner)

wave-proof shielded cable, spherical spacers (not shown) to prevent operation should the cable accidentally get caught in the oven door, and the plug (the plug and probe jack configuration vary with different makes). Models that rotate the food on a carousel or turntable must use a slip-connector type of jack (Fig. 8-48) which allows the probe plug to rotate and remain connected. The key part of the probe is the *thermistor* located within the stainless steel probe tip. A thermistor is a thermal resistor with a high negative temperature coefficient of resistance. In other words, as the temperature increases its resistance decreases.

Figure 8-49 illustrates a commonly used probe detection circuit. Like previous schematics in this section, it has been simplified for explanation purposes and is not intended for actual troubleshooting. When the probe sensor is inserted into the food, the probe plug is connected into the probe jack, the desired temperature is selected, and the oven started. Initially the probe resistance is high (about 50,000 ohms at room temperature), but as the food cooks and the temperature increases, the thermistor's resistance decreases. The detection circuit is essentially a switching device that consists of resistive voltage dividers. As the resistance within the circuit changes, it causes the transistors to switch either "on" or "off". The high resistance of the probe's thermistor causes Q4 to remain "on" so the cook circuit is energized. As the food temperature steadily rises, the resistance of the thermistor gradually decreases until it finally causes Q1 to conduct. At this point the probe has reached the selected temperature and the following switching sequence is initiated: Q1 conducts which turns Q2 "off". This causes Q3 and Q4 to "flip" modes like a toggle switch; Q3 turns "on" causing Q4 to turn "off" which de-energizes the cook circuit.

Microprocessor control has now made *hold-warm* options available. After the product in which the probe is inserted reaches the desired state of preparedness, the computer initiates a low-level RF output from the magnetron which holds the food at a certain temperature for a specified time. Most units have a built-in timing system which terminates this feature after about 60 minutes so the food will not overcook. Most units also have an automatic temperature probe check which verifies that the probe is securely fastened in the jack and is working correctly. If the probe-check circuit detects an open or shorted temperature probe, the oven will not operate in the temperature control mode.

Appendix III contains additional information about the probe and its use. *Section 13.19* outlines various problems associated with the probe and how to verify its proper operation.

8.19 HUMIDITY SENSOR COOKING

Although the day is yet to come when the food hops into the microwave oven all by itself, the day of completely "automatic" cooking is fast approaching. *Humidity sensor cooking* is a big step in that direction. Different manufacturers have various names for this feature, but the fundamental principles of operation are the same: A semi-conductor device detects the moisture (also variously referred to as vapor, humidity, aroma, gas, or steam—depending where you are from, I suppose) that is emitted from foods as they heat. Humidity sensor cooking is based on two factors: 1) the amount of cooking time required for a particular food item to begin giving off moisture, and 2) the data programmed in by the operator which describes that food item. Relative to those factors, the sensor supplies the computer with appropriate information that enables it to adjust the remaining cooking time, power level, and provide "stir", "cover", "stand", or other applicable instructions. The results are impressive.

The key components are a specially designed microprocessor chip in the control unit and the *sensor* itself; a semiconducting ceramic compound composed

Figure 8-48 Two common probe jacks used in turntable models (top view).

mainly of microcrystals of tin dioxide which are bonded into a mass by a heating process called sintering. This ceramic sensor element is very porous, so moisture that is present in the air will enter the semiconducting material and cause its resistance to decrease—as humidity increases the resistance decreases and vice versa. Figure 8-50A shows a sectional view of a sensor element with the corresponding resistance value curve (Fig. 8-50B). Through electrodes, which are embedded in the semiconductor material, this moisture-induced variation of resistance can be used to detect

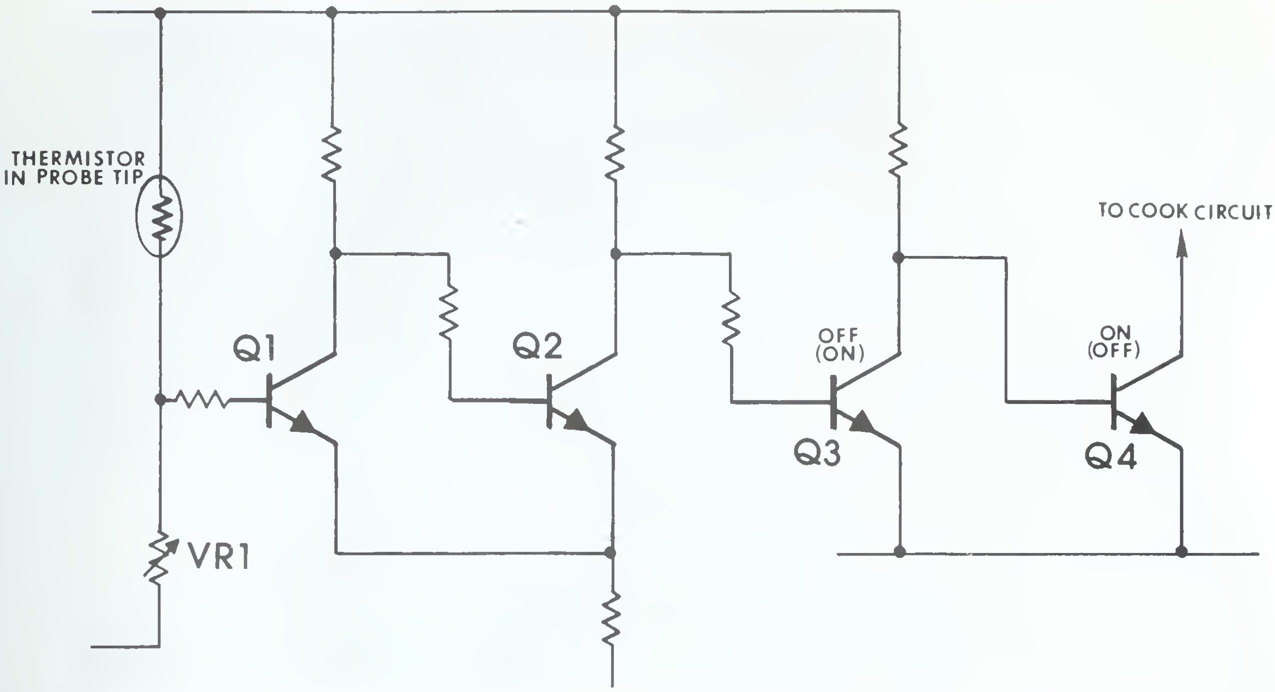


Figure 8-49 Simplified probe detection circuit.

and monitor the relative humidity within the oven cavity. The sensor, located in or near the cavity exhaust vents (Fig. 8-51), is protected by a stainless steel shield with vent holes, or a flame-proof stainless steel wire gauze cover (Fig. 8-52). This is a progressive innovation with different manufacturers producing variations and improvements on a continuing basis. Therefore, three basic sensor-cook designs that represent the larger number will be considered. Following that, an explanation of temperature control in a combination microwave and *convection* oven.

A simple sensor is affected by ambient conditions. So, several operations must take place automatically to stabilize the factors that may distort the sensors response. Each sensor-cook cycle begins with a cleaning period, during which the blower motor operates to ventilate the exhaust vents thus removing any accumulated

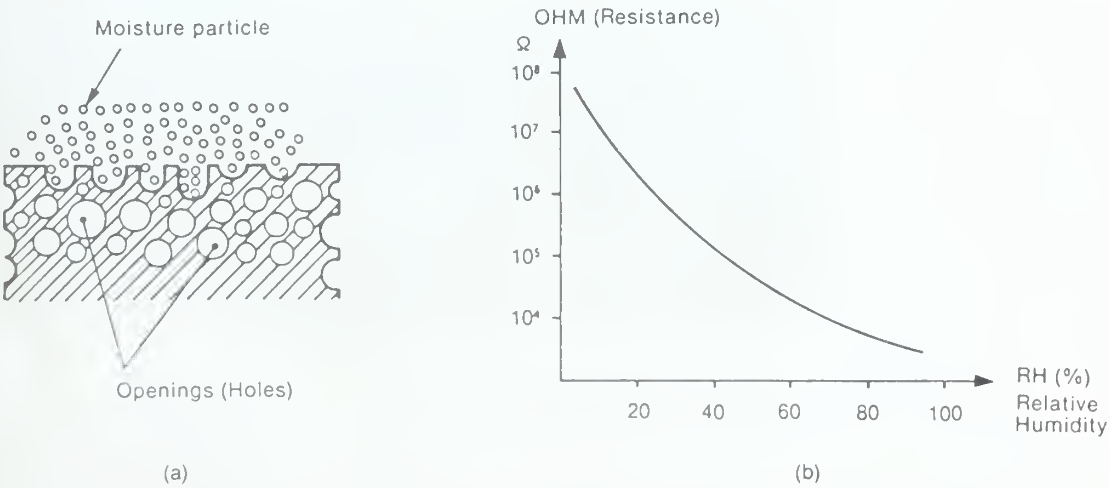
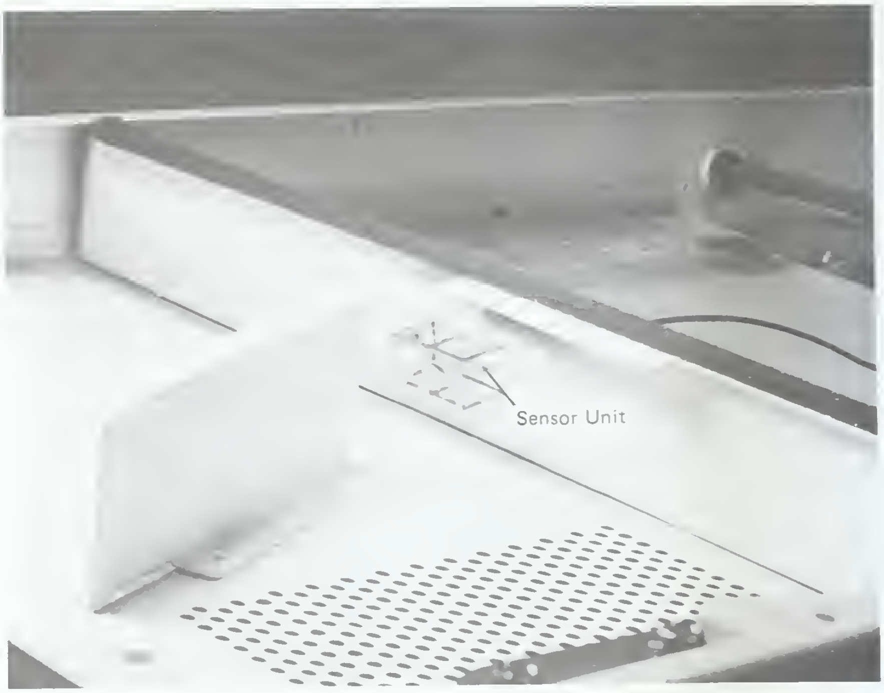


Figure 8-50 Sectional view of a sensor element with corresponding resistance curve. (Used by the permission and courtesy of Matsushita Electric Corporation of America.)



(a)

(b)

Figure 8-51 Typical sensor location.

(c)

Figure 8-51(a)(b)(c) Typical sensor location.

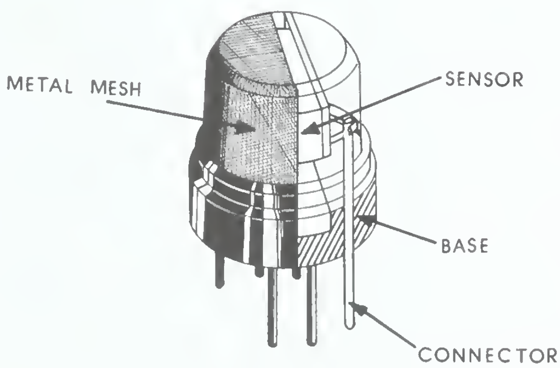


Figure 8-52 Structure of a common sensor unit. (Courtesy of Michael S. Wagner)

moisture, thereby stabilizing the relative humidity within the cavity. After the sensor-cook cycle is completed, another cleaning period occurs. This time a tiny heater coil which is wrapped around the sensor element is energized and heats up to around 450°F (150°C). This burns off any residual moisture or grease and cleans up the element for the next sensor-cook operation. Most sensor-cook systems utilize some sort of a cleaning cycle.

In the first of the three basic sensor cook designs, the sensor initially presents a high resistance to the control section due to the fact that the cavities within sensor are filled with oxygen molecules from the air. These molecules tend to oppose the movement of electrons through the sensor material. However, once the magnetron is energized, the temperature of the food begins to rise. As it cooks, the food eventually reaches a temperature where steam is generated and the relative humidity within the oven cavity begins to increase. As the humid air is ducted out of the cooking cavity and past the sensor, particles of moisture enter the porous sensor material which reduces the concentration of oxygen molecules and the resistance of the sensor gradually begins to decrease. The lower resistance is detected by a control panel circuit similar to the one in Figure 8–53.

In Figure 8–53 the voltage from point "A" to "B" provides a constant reference from which an output (Vs) is created by the difference that develops across the sensor as its resistance decreases. As the food cooks, steam is generated, the ambient conditions become more humid, the sensor resistance decreases, and the sensor output (Vs) fluctuates correspondingly. The output intensity necessary to initiate the next stage of sensor-cook operation is calculated by the microprocessor in the control panel and varies with the type of food being cooked. Once the humidity has risen sufficiently, the resistance of the sensor decreases to a point where the voltage across it creates an output that advances the system to stage two of the sensor-cook operation. Stage one was the time that it took from the start of microwave production to a notable increase in the relative humidity so as to be detected and translated

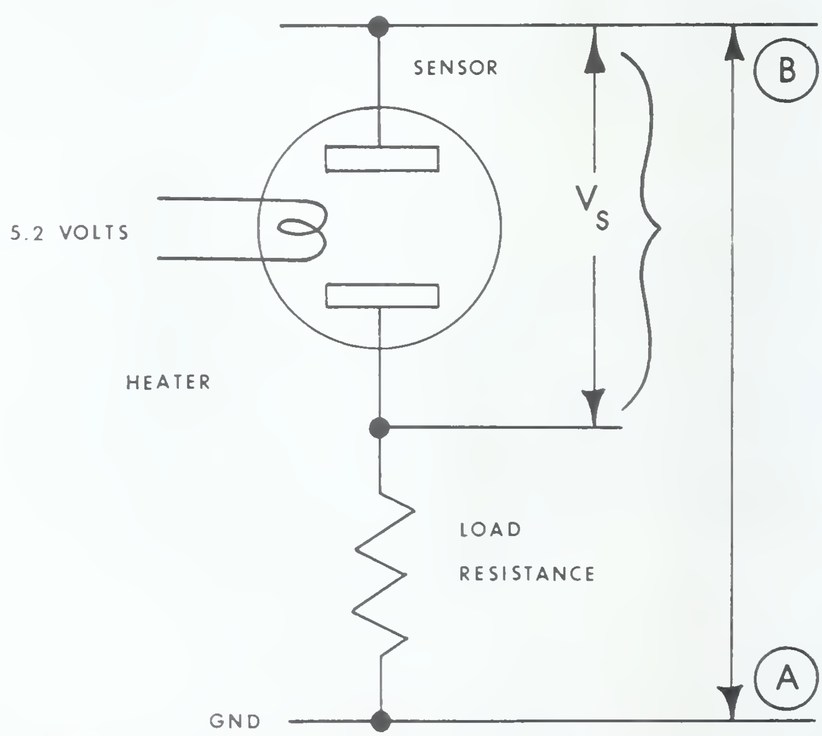


Figure 8–53 Example of a basic sensor circuit. (Courtesy of Michael S. Wagner)

into an output. Stage two essentially takes the sensor out of the circuit and, depending on the type of food, the elapsed time, and other variables, the control panel calculates the remaining cooking time and a suitable power level. At the end of the cooking cycle the signal sounds and the food has cooked automatically—almost.

8.20 ABSOLUTE HUMIDITY SENSOR

This second basic sensor-cook design uses two thermistors. Within the structure of the sensor unit, one thermistor is housed in a closed compartment filled with dry air and the other thermistor is mounted in an open compartment (Fig. 8-54). This system also incorporates cleaning cycles similar to the first design. As Figure 8-55 shows, the two thermistors parallel two control-panel resistors to form a *bridge circuit.* As the ambient humidity begins to change from moisture given off by cooking food, an imbalance is created in the bridge circuit. The different housing conditions cause the thermistors to show different degrees of conductivity. This difference in potential between them causes an output voltage from the bridge circuit. As the absolute humidity of the air increases, so the amplitude of the output increases. After being amplified, the output voltage is sent to the control circuitry which then decides on a remaining time and power level to produce the best results.

8.21 INFRARED SENSOR UNIT

A third method detects the surface temperature of the food using an *infrared ray detector,* a thermistor, and a *chopper blade* (Fig. 8-56). Since a product gives off infrared energy in proportion to its absolute temperature—not just the inner temperature—this sensor effectively detects the surface temperature of the food. When microwave energy is applied to the food, the temperature of the food rises. The resulting heat emanates from the food in the form of infrared rays. As Figure 8-57 shows, these rays must pass the chopper blade in order to be detected by the sensor. The metal blade performs a repeated up-and-down chopping action that is driven by regular synchronized pulses from the control circuitry. The chopper blade cuts through the emanating infrared rays in such a way as to modulate their effect on the sensor detector. The output signal from the sensor is therefore an alternating current that reflects the chopper action. The strength of the output signal is in proportion to

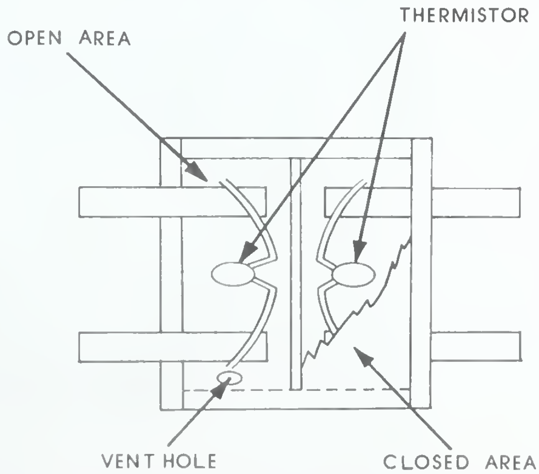


Figure 8-54 Internal structure of an absolute humidity sensor. (Courtesy of Michael S. Wagner)

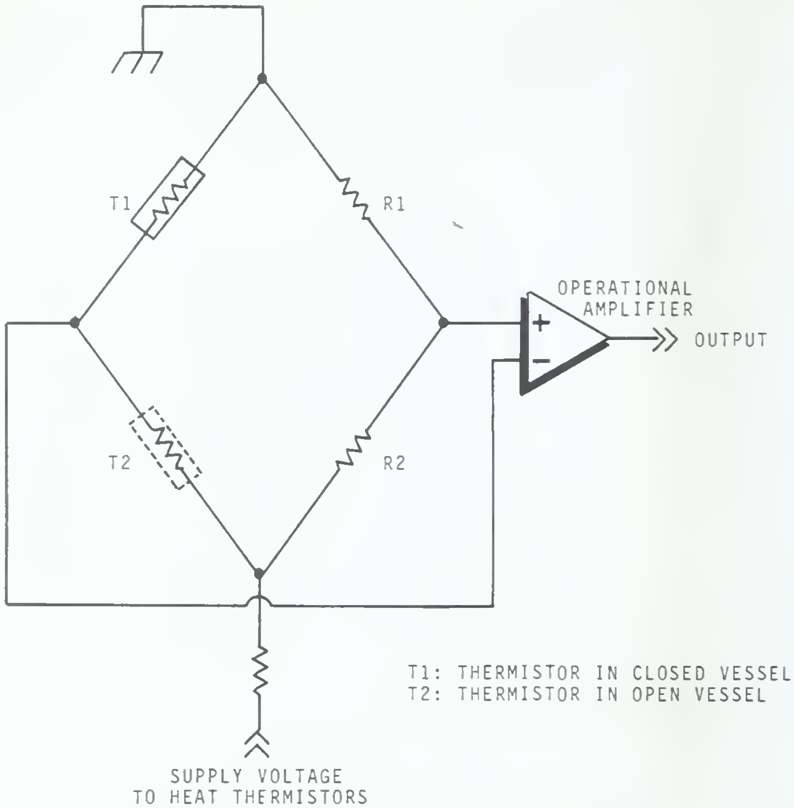


Figure 8-55 Basic humidity sensor bridge circuit.

the difference between the food surface temperature and the temperature of the chopper blade itself (the blade temperature is monitored by an adjacent thermistor). The signal is demodulated, converted to a digital form and sent to the microcomputer which processes the information and directs the remainder of the cooking operation to a savory conclusion.

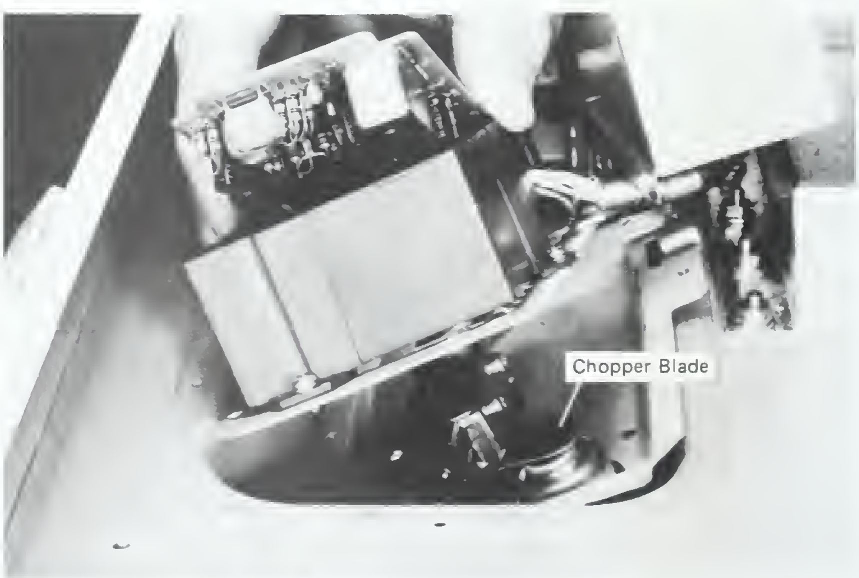


Figure 8-56 Infrared sensor unit.

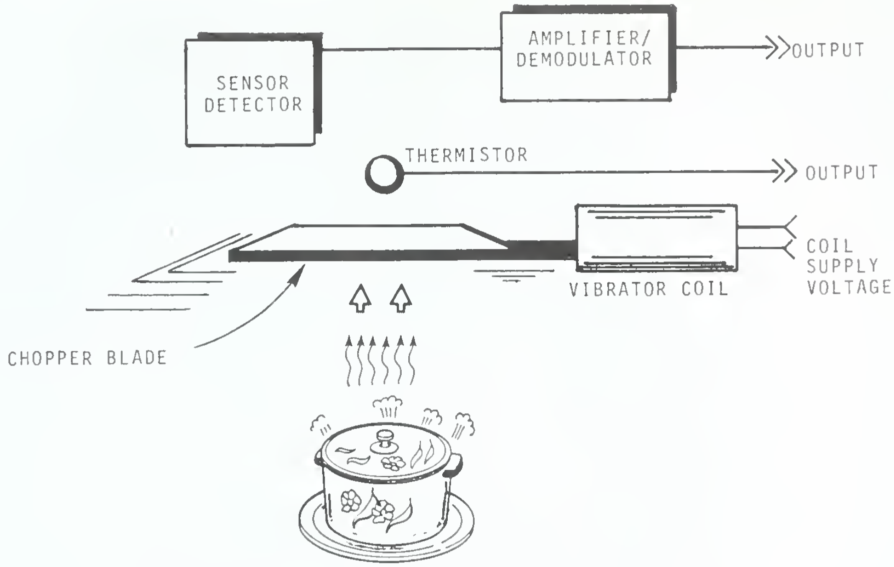


Figure 8-57 Operation of a basic infrared sensor unit.

8.22 CONVECTION COOKING CONTROL

Convection cooking is a hot air heating system in which the food is not heated directly by a heating element, but rather by the forced circulation of the hot air produced by the element. The hot swirling air does not leave the oven after it exits the cavity, but is re-circulated across the heating element and back into the cavity in a continuous cycle. The temperature inside the oven cavity is controlled by a thermistor and the associated sensor circuitry. The thermistor is physically located and positioned so that it continually samples the circulating air. When the temperature in the oven cavity reaches the selected (or factory set) level, the resistance of the thermistor decreases which produces a corresponding *analog* output from the sensor circuit. The control unit receives this output and de-energizes the heater relay, the contacts of which provide the circuit to the heating element. When the cavity temperature drops below a certain point, the detection circuit senses this through the increased resistance of the thermistor and re-activates the heater relay. The heater relay closes its contacts and thus provides a current path to re-energize the heating element, returning the cavity to the selected temperature. The heating element is cycled on and off in this fashion to maintain the appropriate cavity temperature. At the end of the cooking cycle everything shuts down, except maybe the blower motor. If the cavity air is above a certain temperature the thermistor will maintain a circuit that operates the blower motor until the temperature drops below a prescribed level.

8.23 ADDITIONAL CONTROL CONCEPTS

Litton calls it "Auto-cook" and *Sharp* calls it "Compucook", but the computer control is essentially the same in both. A powerful microprocessor within the control circuitry is pre-programmed with the actual menus and proven recipes of a master chef. Under controlled conditions the chef experiments with different recipes by varying the cooking times, the power levels, and other factors, until, finally—"Chef-d'oeuvre!" The combinations of cooking times and power levels that brought the exact results the chef wanted are then translated into computer language and programmed into the microprocessor.

In the consumer's kitchen the conditions are not as controlled, so various stabilizing and compensating circuits (as mentioned earlier) are employed to maintain a degree of consistency. Once the kitchener has programmed in an accurate description of the type, amount, and weight of the food (some new models are equipped with a scale, so the food is weighed automatically), the computer then asks for a preference as to doneness: "rare?" "medium?" "well?" "hot?" "hotter?" Upon receiving an answer the "miniature chef" inside the microprocessor goes to work. During the cooking process the "chef" may signal instructions, such as: "cover", "stir", "stand". Finally, out comes the finished product, beautifully cooked to the praise and delight of the chef de cuisine. This becomes particularly fascinating with the added feature of a computer-controlled voice synthesizer—*especially if it has an accent!*

Safety and Protection Circuits

chapter 9

9.1 INTRODUCTION

For the protection of the user, the servicer, and the oven itself, all microwave ovens are equipped with safety and protection devices. This chapter will cover the various components that make a microwave oven safe, from *interlock switches* that prevent hazardous operation to *protection devices* that prevent damaging operation. Also included is a description of the *containment components* which provide the means to transfer and confine microwave energy while preventing its escape.

Perhaps the most important safeguard is the door interlock system. From one model to the next the differences in construction and configuration are ever increasing, but their purpose and basic operation remain the same in all microwave ovens. The purpose of the interlock system is to interrupt the production of microwave energy when the oven door is opened. And further, to prevent the output of microwave energy until the door is firmly closed and latched.

9.2 INTERLOCK SWITCHES AND CIRCUITS

The interlock switches are activated by the movement of the door or door-latch mechanism; when the door is opened, the *primary* interlock switch actuates (opens) first, and the *secondary* interlock switch actuates (opens) next. Figure 9-1 shows an array of switches which are commonly used in the interlock circuits of microwave ovens. *Snap-action* switches, or as they are commonly called, *"microswitches"* (actually a trade name) operate as their name describes. By lightly pressing a small plastic actuator (or plunger) an internal micro-switching action takes place. The snap action is created internally by a small spring made of beryllium copper (beryllium is a hard noncorrosive metallic element used in copper alloys). Notice in Figure 9-2 that the *interlock switch module* (ISM) incorporates two or more separate sets of contacts, each with their respective actuator arms. When the door is

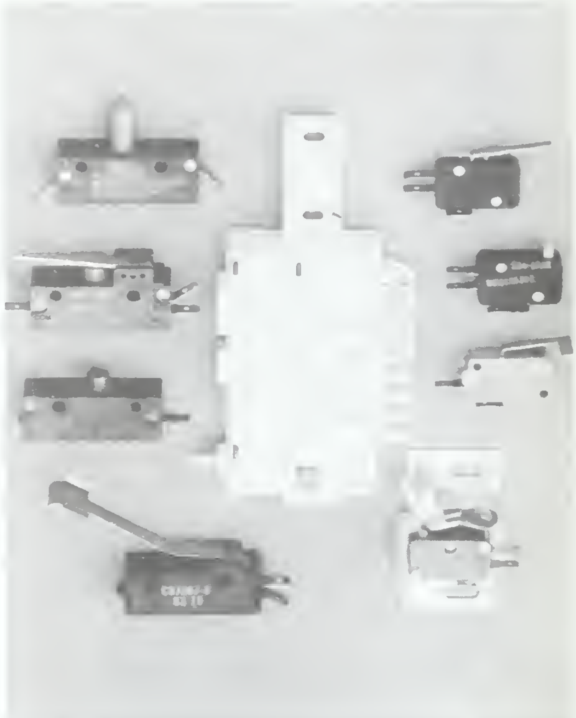


Figure 9-1 Common interlock switches.

closed, the door hook enters the switch module and forces the actuation of the contacts.

There are various types of switches that fit many applications. Switches are classified by the type of switching they perform or by their construction. Their physical differences notwithstanding, they all can be represented by fairly standard schematic symbols as shown in Figure 9-3.

The simplest snap-action switch is the *single-pole, single throw* (SPST). As shown in Figure 9-3A, the SPST switch either makes (closes) or breaks (opens) the circuit between two points on one line.

The *single-pole, double-throw* (SPDT) switch shown in Figure 9-3B has one

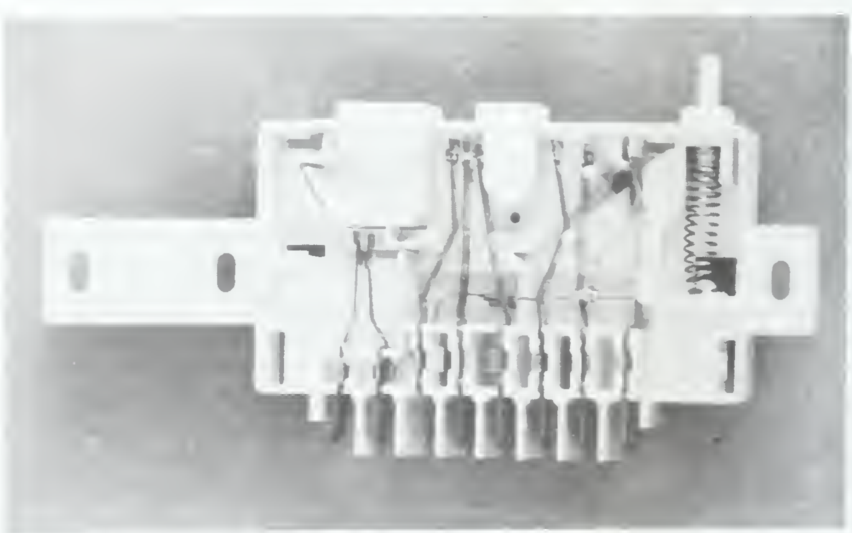
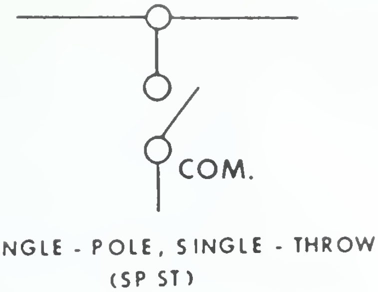
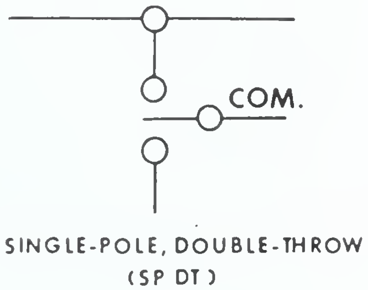


Figure 9-2 ISM internal switching arrangement.

A.



B.



C.

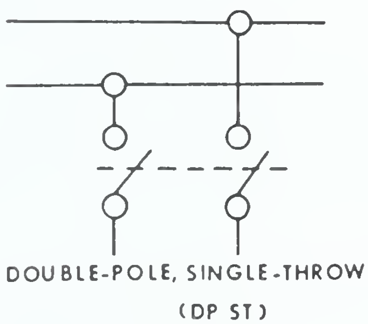


Figure 9-3 Schematic symbols of common switches.

common (COM.) arm (or a single pole) which can be moved into two possible positions. When actuated the SPDT switch closes one circuit while opening another.

Not as common in the interlock circuits of microwave ovens is the *double-pole, single-throw* (DPST) switch (Fig. 9-3C). The DPST switch has only one position of closure but controls two separate circuits simultaneously. It comprises two sections which are mechanically, but not electrically connected.

To appreciate the logic of microwave oven schematics, in regard to the switches, the terms *normally open* (N.O.) and *normally closed* (N.C.) must be understood. The schematic designations correspond to those on the casing of the switch itself (Fig. 9-4). How is the "normal" position determined? Visualize the switch out of the oven and lying on a table *by itself* — the contacts are then in their "normal" position.

All switches have a *voltage and current rating* which refer to the current-carrying and switching capability of the switch contacts. A typical door interlock switch is rated at 15 amps (current is measured in *AMPeres),* with 125 to 250 VAC applied, at a line frequency of 50 or 60 Hz. When replacing an interlock switch these ratings, particularly the current rating, must be met or exceeded; otherwise, premature switch failure will result.

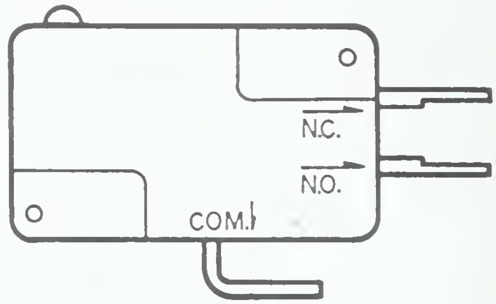


Figure 9-4 Switch terminal designations.

Although the difference may be indiscernible, the *operating* and *release force,* or the relative amount of pressure needed to actuate the switch, can vary considerably. Visually two switches may appear the same, with the same voltage and current ratings, and yet, because they were intended for dissimilar applications, they require quite different amounts of operating pressure. Like the voltage and current ratings, this factor is also a very important consideration when replacements are made.

Before considering some typical interlock-switch circuitry, another very important switch must first be introduced. That is the *interlock monitor switch.*

9.3 INTERLOCK-MONITOR SWITCH

All microwave ovens made after October of 1971 are covered by a Federal radiation safety standard (CFR 21, Part 1030) enforced by the Food and Drug Administration. In August of 1974 a safety revision went into effect requiring that all microwave ovens manufactured on or after that date be equipped with an interlock monitoring system. This Federal law states that the monitoring system "shall cause the oven to become inoperable and remain so until repaired if the required safety interlock(s) should fail to perform [their] required functions." Compliance to the law is accomplished by a fail-safe type of system that monitors the operation of the door interlock switches. The principle component of the monitoring system is the *interlock monitor switch.* The monitor switch is also referred to as a *safety switch, short switch, sensing switch,* and a *failure detector switch* (F.D.S.). The interlock monitor system comprises one or both of the door interlock switches, in some models the cook relay, the monitor switch itself, and a line fuse arrangement.

Interlock-monitor circuits, while serving the same purpose, come in a wide variety of configurations. To enable a broad understanding of their operation, four of the more common monitor circuits, with irrelevant components omitted for simplification, will next be considered. Actually most other arrangements are merely variations of at least one of these basic systems illustrated in Schematics #1 through #4 of Figure 9-5. To better visualize their respective positions when the door is open, and when the door is closed, each switch has been drawn with two arms. In each of the following schematics, the dashed arm represents the position of the switch when the door is open, and the solid arm its position when the door is closed.

Schematic #1 (Fig. 9-5)

In the first arrangement the line fuse, the primary interlock switch, and the monitor switch are involved in the monitor loop. It is a loop that under normal circumstances will never be closed. With the door closed, and the cook-relay contacts closed, power is applied to the primary winding of the high-voltage transformer and the oven cooks. Opening the door in mid-cycle opens the primary and the secondary interlock switches which breaks the circuit to the transformer at those

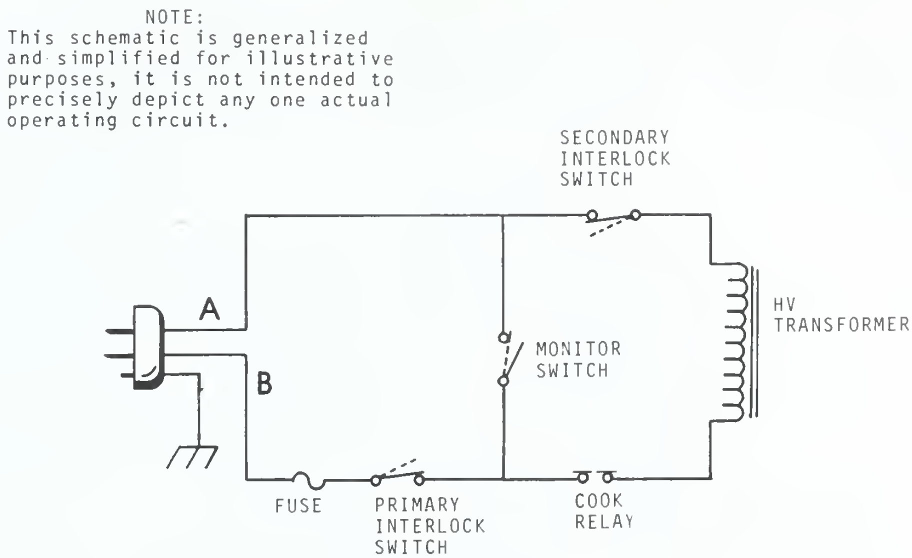


Figure 9-5 Schematic #1.

two points. The oven stops cooking. Now, close the door again and the oven begins cooking. This time when the door is opened, suppose the primary interlock sticks closed — in other words, it fails to open. However, as the door opens, the monitor switch appropriately closes. This creates a direct short circuit from point "A", through the closed contacts of the monitor switch, through the malfunctioning (closed) contacts of the primary interlock, and to the fuse — which "blows" with vehemence. In fact, the fuse "blows" or opens so violently under these circumstances that special fuses, designed not to shatter or blow apart, must be used. With the line fuse open, the oven goes completely dead, as if unplugged. At this point service is required to restore the oven to operation. Indeed, the principle reason for fusing a microwave oven is for the fail-safe protection of the interlock-monitor circuit.

Schematic #2

In this circuit the cook relay has been included in the monitor loop. So, if the door were opened during a cook cycle, *both* the primary interlock switch *and* the cook relay contacts would have to fail in the *closed* position to create the loop through the monitor switch contacts which would "blow" the fuse. If only one set of

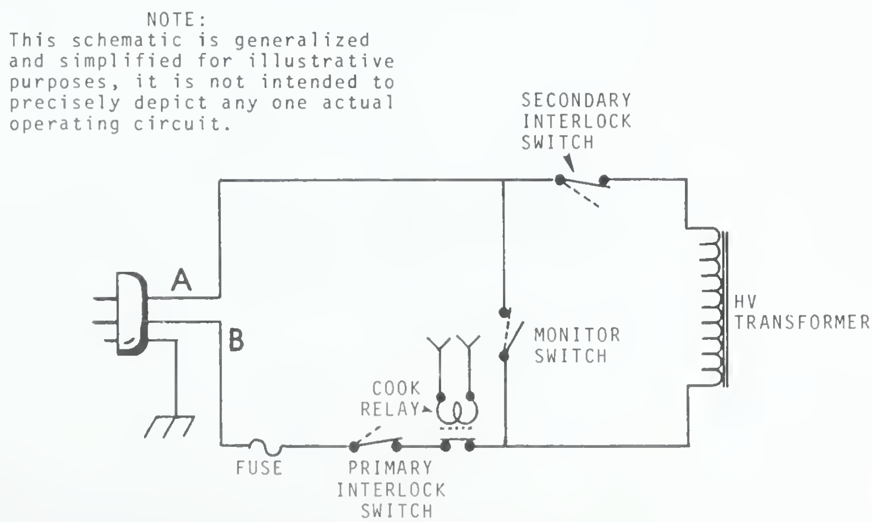


Figure 9-5 Schematic #2.

contacts, either those of the interlock switch or those of the cook relay, failed in the closed position, the fuse would remain intact and the oven would continue operational. No danger would exist, however, because the functional set of contacts would still serve to interrupt the circuit to the transformer when the oven door was opened.

Schematic #3

Monitor systems that involve more than just one switch (such as the one described here and the one described in *Schematic* #2) are more positive and easier to troubleshoot. While they provide the same monitoring function of the interlock system, the occurrence of nuisance "fuse-blowing" problems are comparatively minimal. In this circuit both interlock switches are involved, so both interlock switches would have to malfunction at the same time in order to "blow" the fuse. However, suppose the monitor switch hesitated or failed to open when the door was closed — yes, a "dead" oven would result. This is not an unusual problem, especially in door-slamming families.

Schematic #4

In somewhat of a departure from the previous three, this system is a little more complicated, but much less fallible. Almost unique to *Amana* and *Amana-made* models, this circuit incorporates an effective time-delay mechanism comprised of a thermal fuse situated inside of a tube resistor as shown in Figure 9-6. The fuse is non-resettable and opens (actually melts) if ambient conditions reach a certain temperature. The temperature at which a given fuse will melt is usually indicated on the fuse casing. The tips (end-seals) are also color coded, but the lack of an industry standard makes this rather useless except for matching within related brands. The value of the tube resistor also varies with different models. As schematic #4 shows, a failure of the left interlock to open when the oven door is opened, would create a short circuit through the sensing switch contacts (which close when the door opens), across the tube resistor, and through the thermal fuse. Although the current flowing through the resistor causes it to heat up rapidly, it takes approximately 5 to 10 seconds before reaching the melting point of the fuse. During this time delay the further operation of the oven has already been prevented by the open latch switch and consequent opening of the cook relay. Once the fuse opens the servicer has little trouble in pinpointing the problem. Even if the left interlock switch functions properly upon examination, the servicer knows that when the interlock protect fuse

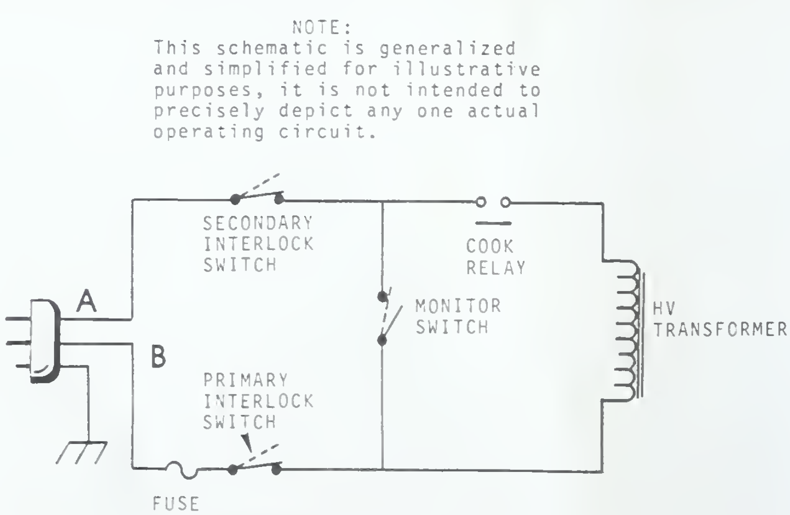


Figure 9-5 Schematic #3.

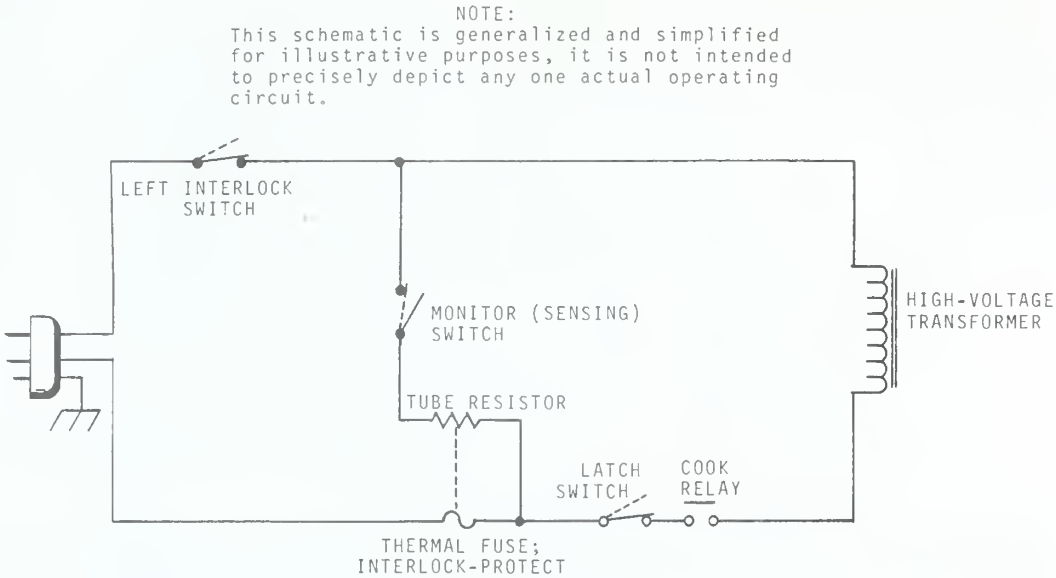


Figure 9-5 Schematic #4.

is open, the switch is either defective or out of adjustment. Transient voltage spikes, power surges, and voltage drops that cause aggravating intermittent fuse failures in many ovens, are not a factor here.

In the vicinity of the interlock protect fuse-resistor assembly there is usually another similar fuse arrangement, but with different values and a different purpose. This is referred to as the *transformer*-protect fuse and in many models, the tube resistor which surrounds the transformer-protect fuse is made of glass. As shown in the simplified schematic of Figure 9-7, the transformer-protect tube resistor is electrically located in the secondary or the high-voltage section. There, it protects the high-voltage transformer by monitoring the operation of the high-voltage components. A shorted high-voltage diode for example, would dramatically increase the current flow through the resistor causing it to quickly heat up. Physically the thermal fuse is inside of the resistor, but electrically it is in the distant primary circuit. When the resistor's temperature reaches the fuse's melting point (approximately 333°F) the fuse opens the primary circuit, and the oven becomes inopera-

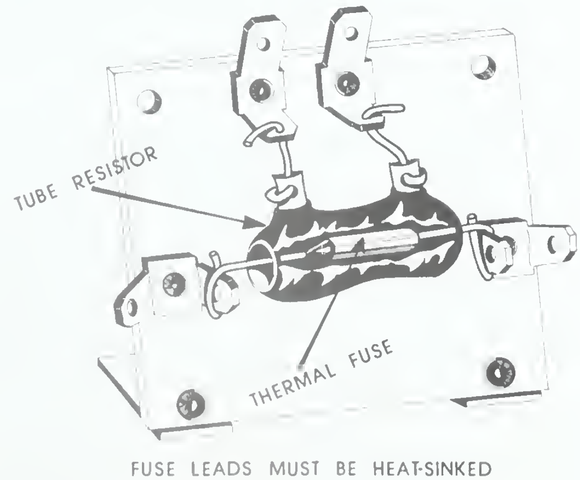


Figure 9-6 Interlock protect assembly. (Courtesy of Michael S. Wagner)

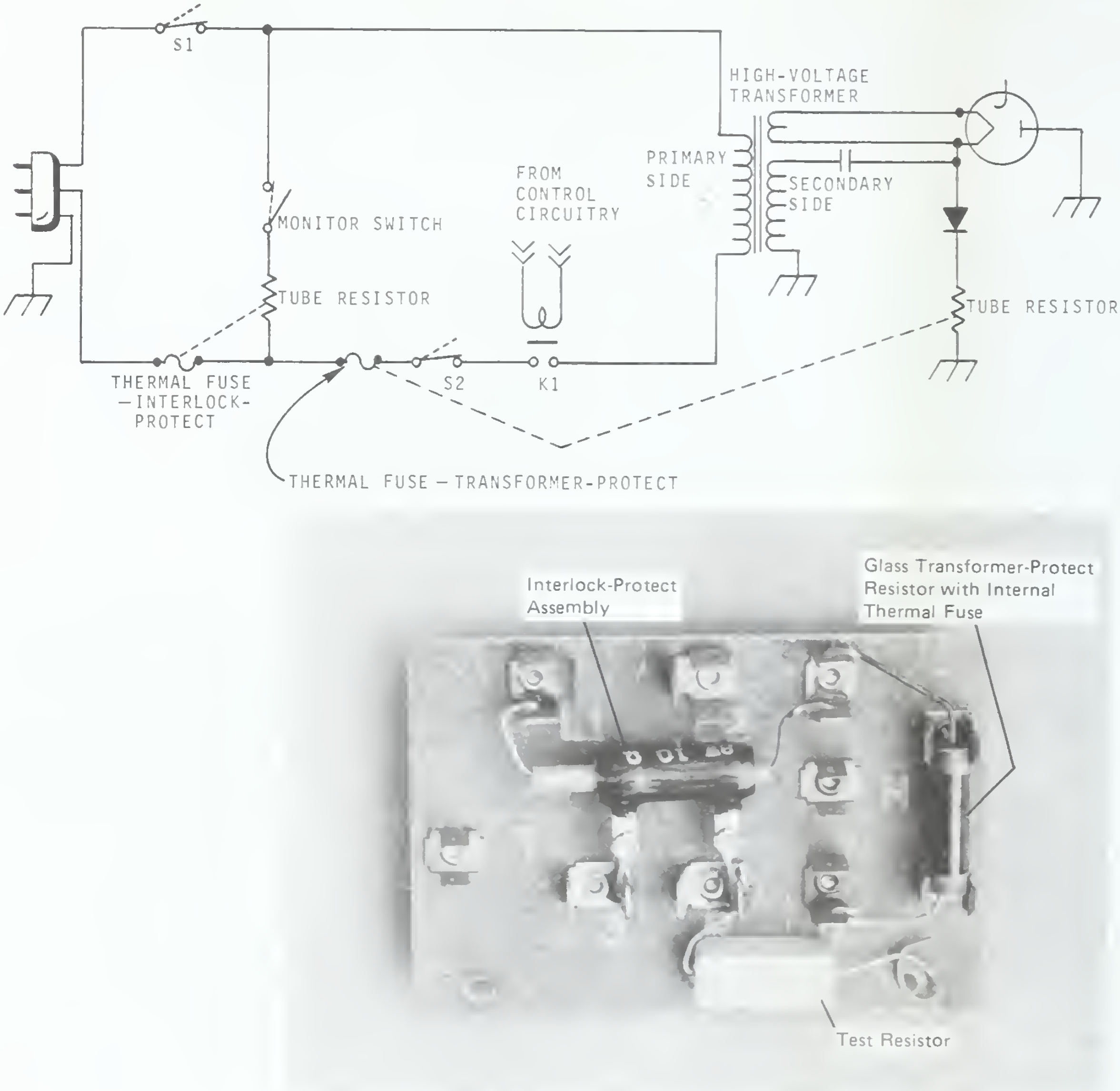


Figure 9-7 Representative interlock-protect and transformer-protect circuit.

tive. The servicer is able to recognize the open fuse as the *transformer*-protect fuse and, thereby, promptly isolates the shorted diode. With replacement of the shorted diode, the opened thermal fuse must also be replaced. The new thermal fuse must be soldered in place. Stop! If you do not heat-sink the leads of the fuse, the heat of the solder will damage the fuse link and you will wonder why the oven is still "dead" *after* you have replaced the fuse. This applies to the interlock-monitor, the transformer-protect, and all other thermal fuses which must be soldered in place. For a more detailed explanation of this or other replacement procedures refer to *Section 14.5.*

9.4 INTERLOCK SEQUENCING

To minimize intermittent fuse failures it is essential to insure that the interlock system is operating in the proper sequence. In other words, the time interval between the opening of the interlock switches and the closing of the monitor switch must be

sufficient to avoid even the slightest overlap. While a slight overlap between the opening of the interlock switch and the closing of the monitor switch may not be sufficient to "blow" the fuse, it may be enough to weaken the fuse to the extent that it fails during a cook cycle. This creates a very misleading symptom as to the true source of the problem.

Conversely, the following dangerous possibility would exist if the sequence were adjusted so that the transfer was too far apart: If an interlock switch malfunctioned so that it failed to interrupt the cook cycle when the oven door was opened, the operator could be exposed to dangerous amounts of microwave radiation. The exposure would continue until the door was opened far enough to finally actuate the mis-adjusted monitor switch and thus open the fuse.

9.5 INTERLOCK PROTECTION POSTSCRIPT

Whenever a fuse fails due to the action of the interlock monitor circuit, particularly in cases of multiple fuse failures, it is advisable to replace all switches and contacts that were subjected to the damaging surge of current. Due to the fact that switch, relay, and other involved contacts are invariably weakened or damaged under these circumstances, many manufacturers make this procedure mandatory.

Under no circumstances leave a microwave oven operational with the interlock monitor system disabled or defeated.

The failures discussed here are real. The accompanying schematics have been simplified to promote understanding. These and other types of failures, with their related symptoms and corrective measures, as well as replacement and adjustment procedures are discussed in *Sections 14.2.* and *14.3.*

9.6 ADDITIONAL SWITCH APPLICATIONS

The *light switch,* which may be mounted separately or combined with a SPDT door interlock switch, supplies power to the cavity lamp when the oven door is opened.

Adding to the frustration of resolving the problems of a microwave oven is the occasional *wrapper interlock switch*. This switch, also called the *cover* or *outer case interlock,* renders the unit inoperable when the cover is removed. *Embarrassment,* is troubleshooting a "dead" oven, only to find a deactuated wrapper interlock switch. ". . . Aha! There it is . . ." is a good remark to make if onlookers are present—as though each oven had its own unique location for the wrapper interlock switch. Once found, it must be temporarily defeated (which, in some models, can be a challenge in itself) in order to perform operational tests on the oven with the cover removed. Figure 9–8A shows the rear panel/outer case-interlock switch of a commercial *Amana* model. *Hobart's M310* and *M312* models use a wrapper interlock that is activated by a bumper on the right-hand endcap, as pointed out in Figure 9–8B. And, Figure 9–8C locates the wrapper/timer panel-interlock assembly of a popular *Litton* model.

The *panel interlock switch* serves the same purpose, except that it involves the oven's front panel or air intake grill. As shown in Figure 9–8D, the switch in this commercial *Amana* model is situated behind the bezel insert bracket and is actuated by an allen screw. The allen screw, which also secures the grill in place, is accessed through an opening in the air intake grill.

The Logic switch, also referred to as the *stop* or *sensing* switch (not to be confused with *Amana's* interlock protect *sensing* switch), *senses* when the oven door has been opened and *logically stops* the control panel countdown. In some touch control models made by *Sharp,* which includes *Montgomery Ward* models, the

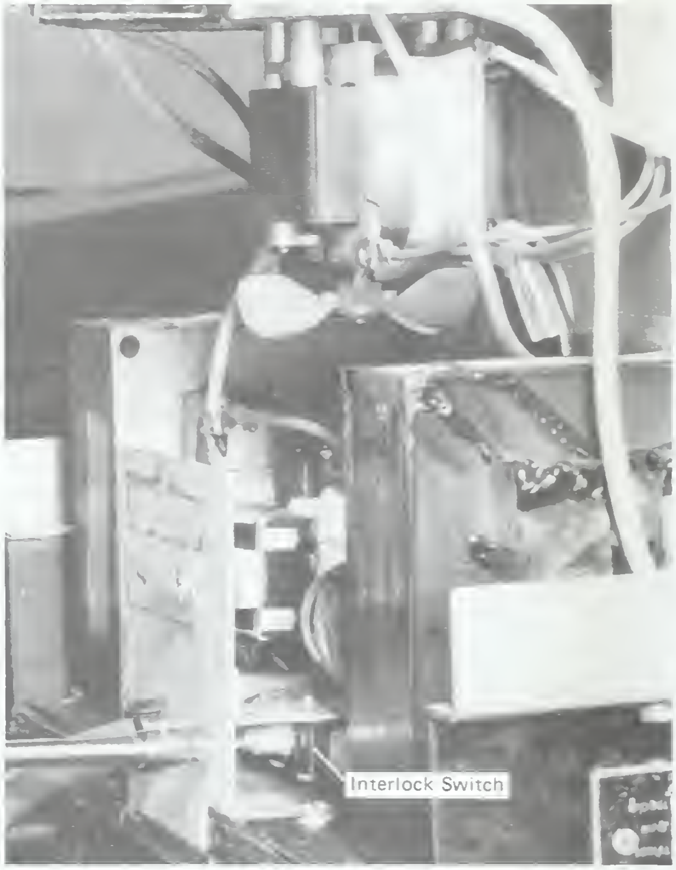


Figure 9-8A Amana outer case-interlock switch.

proper adjustment of the stop switch is critical. When the oven door is closed, the stop switch must also be in the closed position. If, due to misalignment, it remains open at times, the control panel will not respond to programming at those times. A considerable number of control panels and key units have been erroneously replaced due to this deceiving symptom.

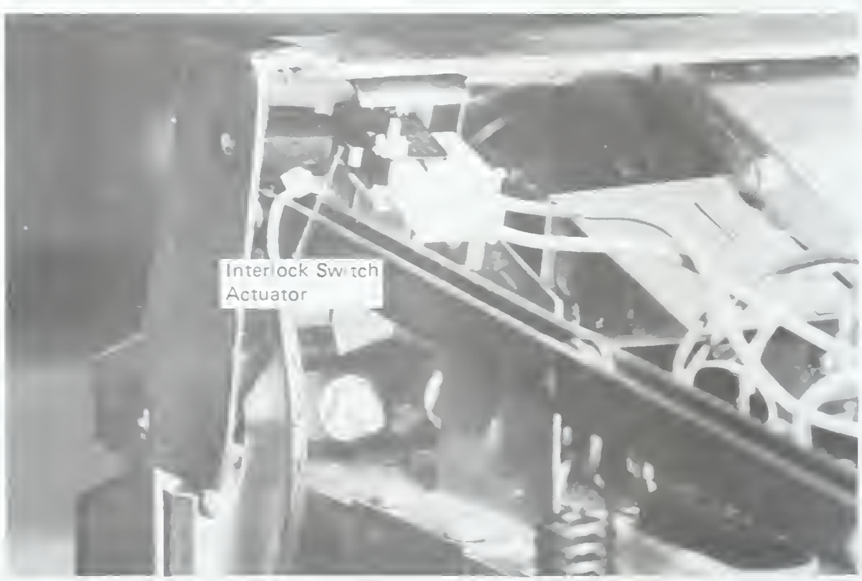


Figure 9-8B Hobart wrapper-interlock switch.

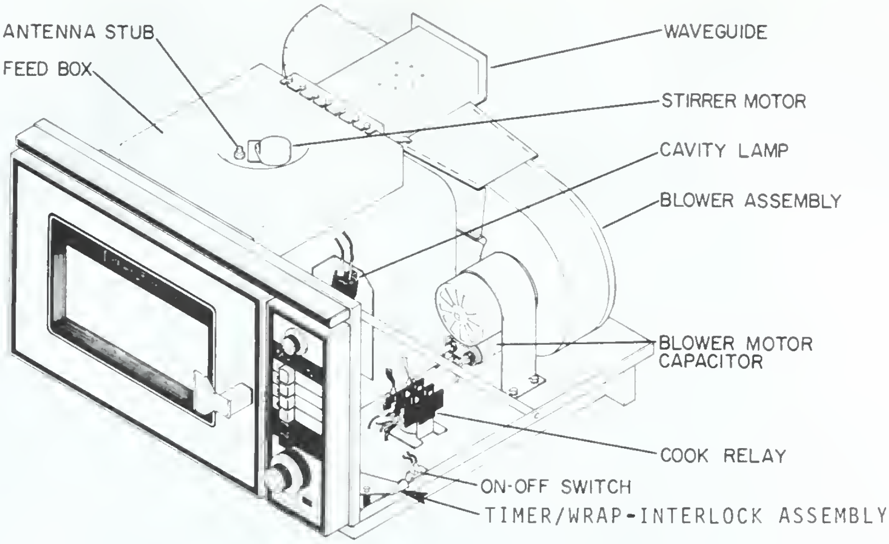


Figure 9-8C Combination timer panel & wrapper-interlock assembly. (Illustration taken from service literature copyrighted 1978 by Litton Microwave Cooking Products. Used by permission.)

9.7 PROTECTION DEVICES

Protection devices monitor the various operating characteristics of a microwave oven. The areas monitored are *temperature, voltage,* and *current.* If an abnormality is detected in any of these areas, the protective device opens appropriate circuits in order to avert damage to the component that it serves to protect.

9.7.1 Thermal Protectors

The device that is used in microwave ovens to monitor operating temperatures is the *thermal protector* (TP). This heat-sensitive switch is also variously referred to as a *thermal cutout, thermal switch* or *thermostat.* Figure 9-9 illustrates the internal

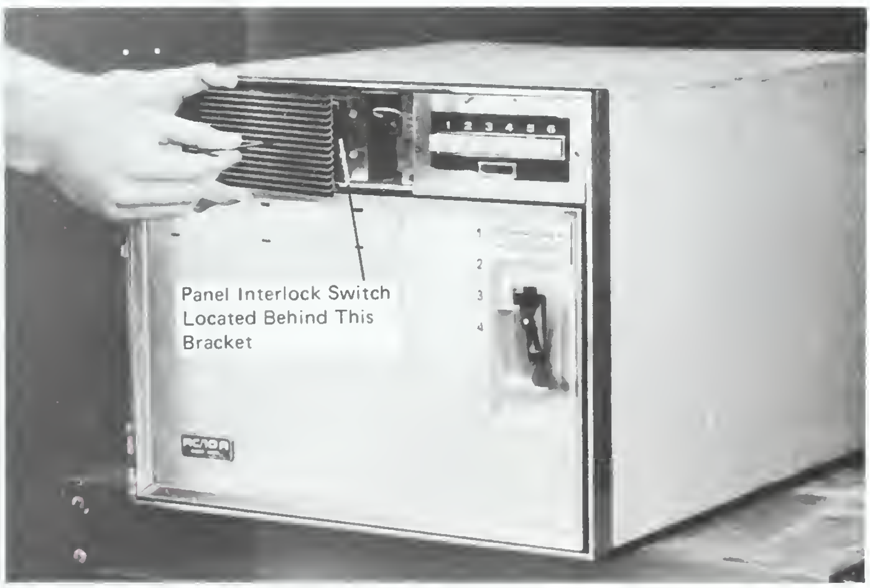


Figure 9-8D Front panel-interlock switch location.

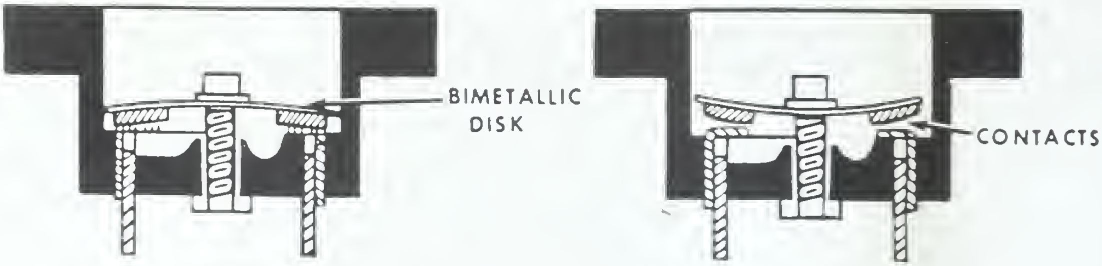


Figure 9-9 Internal switching action of a thermal protector.

heat-actuated switching action of a very common type of thermal protector. When the operating temperature of a component exceeds a safe value, the bimetallic disk inside of the thermal protector bends so as to open its internal contacts, thereby opening the circuit to the component. When the bimetallic disk cools sufficiently, it bends back and resets or closes the circuit. Such is the operation of a *resettable* type of thermal switch. A Thermal *fuse* (Fig. 9-10), on the other hand, is *non*-resettable and, like a fuse, must be replaced when tripped.

The **magnetron** tube is usually outfitted with a thermal switch, or on some models a thermal fuse, both of which are designed to prevent damage to the magnetron if an overheating condition occurs. As pointed out in Figure 9-11, if the thermal protector is not mounted directly on the magnetron tube housing, it can be found in a suitable proximity to monitor the operating temperature of the tube. The temperature at which a thermal protector opens is usually indicated on its casing, many times preceded by an "L". For example, L260 would indicate a "cut-out" temperature of 260°F. Typically, magnetron thermal protectors range from 208°F (98°C) to 300°F (149°C), depending on the physical proximity to the magnetron tube housing.

When the magnetron thermal protector opens, it always opens the circuit to the magnetron. However, because of different circuit configurations, an open magnetron TP can cause a wide range of symptoms from "no heat" to "no program-

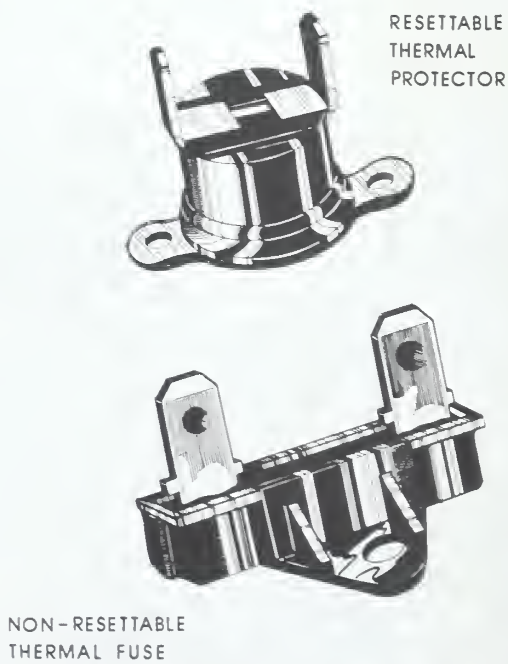


Figure 9-10 Typical thermal protector and thermal fuse. (Courtesy of Michael S. Wagner)

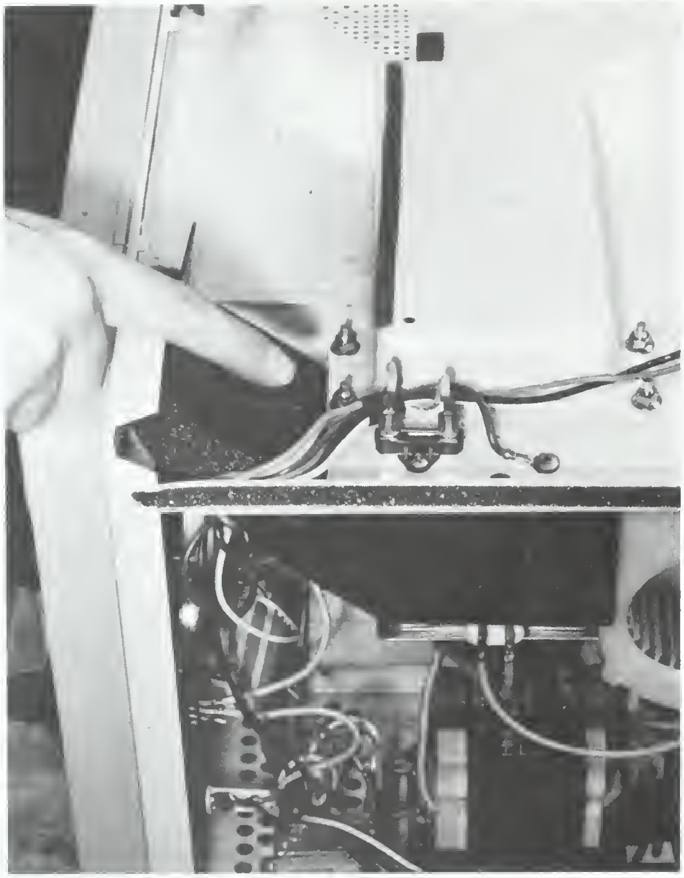


Figure 9-11 Magnetron thermal fuse.

ming" to "no functions at all—completely dead." If the symptoms disappear after a while, but re-occur after a period of operation, the thermal protector is involved. Possibly an intermittent blower motor, or insufficient air circulation to the oven is causing the overheating condition. The effect of a tripped thermal protector on a particular unit can be simulated by testing the operation of the oven while one of the thermal protector leads is disconnected. **(CAUTION!** Unplug the oven and discharge the high-voltage capacitor(s) and by-pass (RF) capacitors before touching any circuit wiring.)

The **cavity thermal protector** is basically the same as the aforementioned, except it monitors the cooking cavity or cavity exhaust temperature. The maximum opening temperatures of cavity thermal protectors vary according to model and relative location. Typically, they range from 175°F (79°C) to 266°F (130°C).

In combination microwave-convection models, the trip temperature of the cavity thermal protector may range as high as 350°F (119°C). As discussed previously in *Chapter Eight,* the cavity temperature of some of these combination units is monitored and controlled by a thermistor.

9.7.1 Ferrite Isolator Thermal Protectors

In commercial and vending operations, a microwave oven will quite often be subjected to "no load" operation; that is with nothing in the cooking cavity to absorb the microwaves. Metallic objects are also, inadvertently or otherwise, put in these commercial ovens. These abuses, intentional or not, result in microwave energy being reflected back to the magnetron tube. Unless this reflected energy is

intercepted or prevented it can ultimately destroy the magnetron tube. Enclosed within the waveguide of commercial *Amana* microwave ovens is a patented *Ferrite Isolator* unit (Fig. 9–12). Acting like a one-way mirror, the isolator allows energy to pass freely from the magnetron, through the waveguide, and into the cooking cavity, but allows very little energy to pass in the opposite direction. During no-load or other abusive operation, most of the reflected energy is prevented from reaching the magnetron by two ferrite discs, which are covered top and bottom by two permanent magnets. The magnets establish a magnetic field around the ferrite discs, which causes the plane of the electric field to rotate by 90 degrees. In other words, as Figure 9–13 illustrates, the reflected energy is rotated and thus diverted into the *load arm* where it is absorbed by blocks of a silicon carbide (SiC) material. The load arm is perforated, outfitted with cooling fins, and extends outside of the waveguide. As the load material absorbs the reflected energy it heats up, its heat-refracting qualities causing the temperature of the load arm housing to increase. Attached to and monitoring the temperature of the load arm(s) is one or two (in dual-tube models) *normally-closed* thermal protectors as shown in Figure 9–14. In most cases, those which are mounted toward the rear of the unit are the *normally-closed* thermal protectors (those mounted toward the front are *normally open* and serve a different purpose which will be considered in the next paragraph). In more recent models, the same temperature-monitoring function is accomplished by only two thermal protectors; one normally closed, one normally open. In dual-tube models, these two thermal protectors are mounted side-by-side on a metal plate *(thermal plate)* which is attached to and thus monitors the temperature of both isolator arms. Each protector is identified by a colored dot; one protector is normally closed and is identified as such by a yellow dot, the other is normally open and is distinguished by a green dot. The trip temperature (or temperature at which the contacts open) of the normally closed thermal protector is approximately 250°F (121°C). These same contacts re-close (or reset) when the unit cools to about 150°F (66°C). Therefore, prolonged operation with insufficient food loads (microwave popcorn is borderline), or metallic objects, will cause the isolator to heat up, thereby causing the thermal protector to open. The contacts of the thermal protector interrupt the line voltage supply, so that the oven remains inoperative until the isolator has sufficiently cooled and the protector resets. This usually takes about 2 to 5 minutes depending on the circumstances.

Prior to oven shutdown, however, and in an attempt to avert that situation, the blower motor is energized by another thermal switch which is also attached to

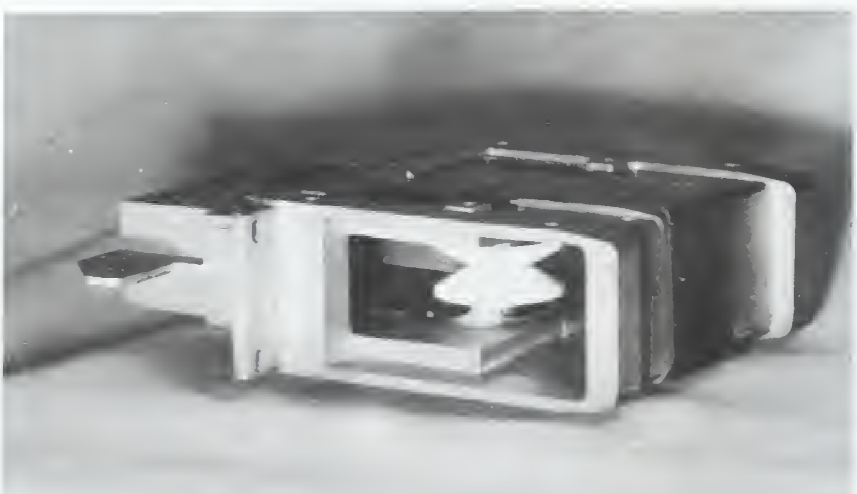
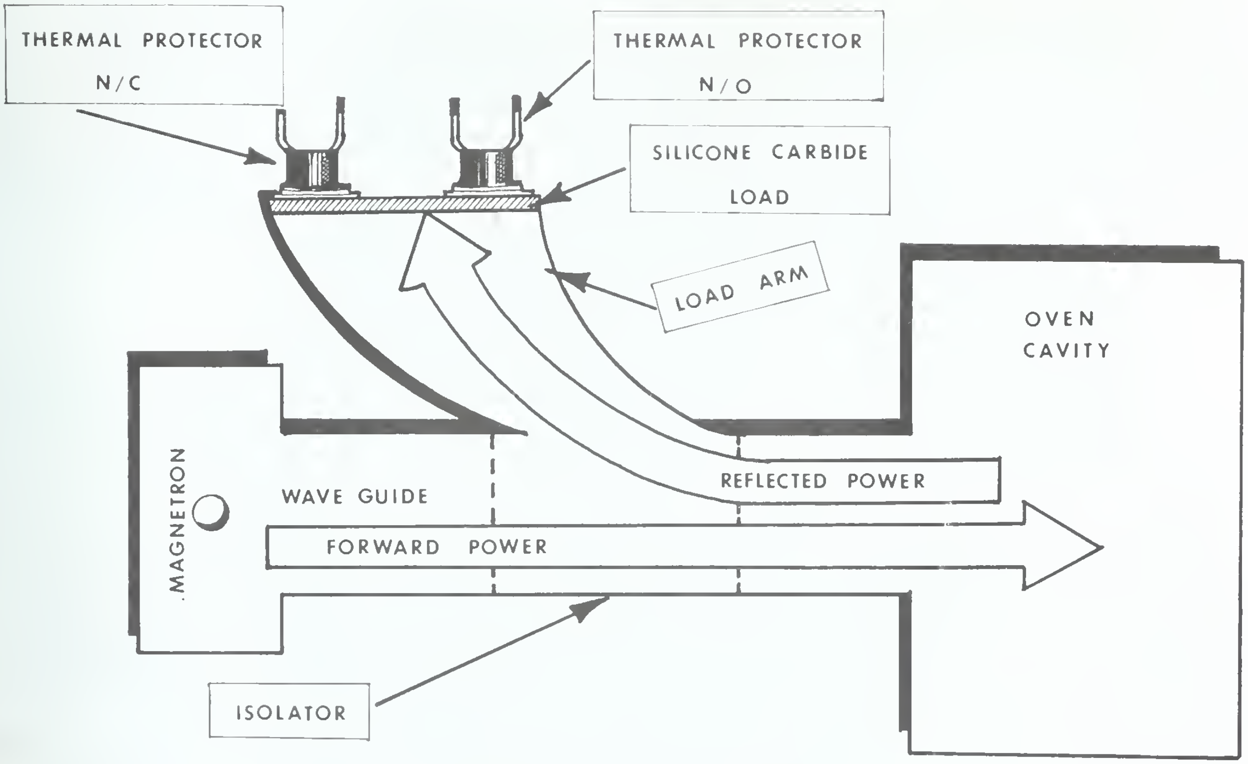


Figure 9–12 Ferrite isolator unit.



FERRITE ISOLATOR

Figure 9-13 The isolator acts like a one-way mirror to reflected energy. (Courtesy of Michael S. Wagner)

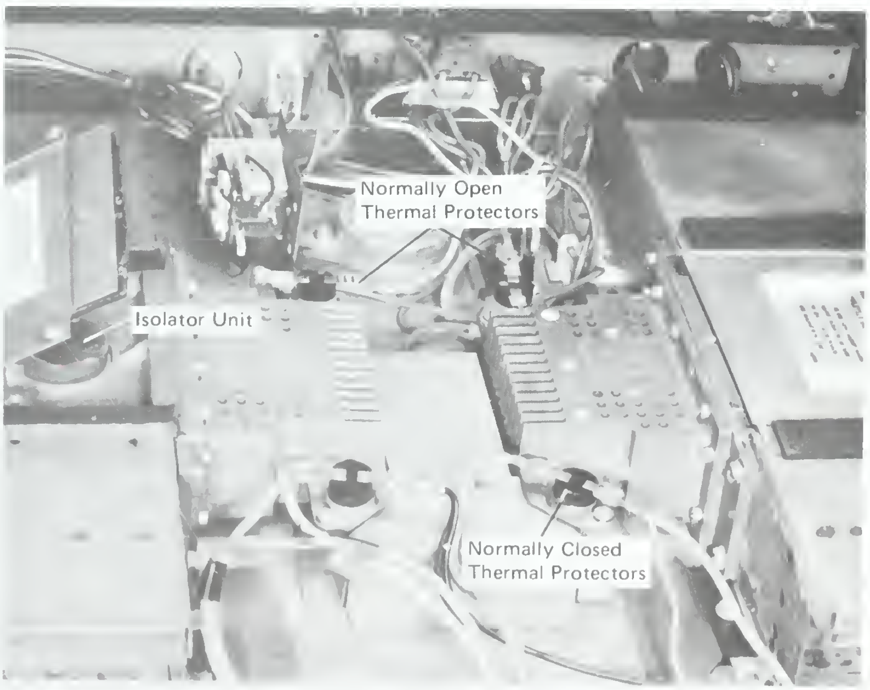


Figure 9-14 Ferrite isolator thermal protectors in a dual-tube model.

the load arm (toward the front of the unit). When reflected energy causes the isolator to reach approximately 160°F (71°C), the normally open contacts of this thermal protector activate to operate the blower motor, which runs until the isolator cools down to about 125°F (52°C). When closed, the contacts of this thermal switch override virtually everything, so that under these circumstances the blower runs continually, even when the oven door is opened—a factor that has been the basis for many a worried phone call. Nonetheless, the reflected energy is "isolated", the perpetrator is frustrated, and the magnetron is protected.

9.7.3 Non-resetting Thermal Fuses

While some non-resetting types of thermal cut-outs resemble their resettable counterparts, most thermal fuses look like the one illustrated in Figure 9-15. As mentioned earlier, these serve the same purpose as their fellow resettable protectors, except once tripped they must be replaced. Why use the resettable type in one application and the non-resettable type in another? Protectors that automatically reset are generally used in areas where temporary or occasional overheating conditions may occur due to circumstances other than an oven malfunction. No service would or should be required in these cases. On the other hand, non-resettable thermal fuses are used in applications where an overheating condition would be as a result of a malfunctioning part, a potentially damaging lack of air circulation, gross misuse, or some other failure where a service call would be appropriate; either for correction, instruction, prevention, or any combination thereof.

Furthermore, for the reasons just stated, a resetting type of protector should *never* be interchanged with a non-resetting type.

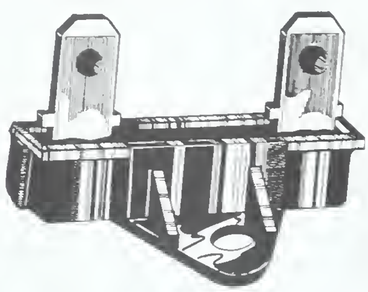


Figure 9-15 Typical thermal fuse. (Courtesy of Michael S. Wagner)

9.8 VOLTAGE PROTECTION DEVICES

Transient voltage surges can be caused by a nearby lightning strike, the cycling of electric motors as in heating or air conditioning systems, or switching within the high-voltage system of a microwave oven. Associated with a voltage spike is a high-amperage current surge that can sweep through and devastate an electrical network. A brief high-voltage surge of 600 volts will damage most solid state devices. A spike approaching 1200 volts can harm even standard appliances. For protection against these over-voltage spikes and high current surges, most microwave ovens are equipped with various suppression and protection devices such as those exhibited in Figure 9-16.

9.8.1 Varistor

The typical metal oxide *varistor* (MOV) shown in Figure 9-17 is a two-electrode semiconductor with an internal resistance that is dependent on the applied voltage. At the rate the voltage increases, the varistor's resistance sharply and quickly decreases. For example, in the event of a surge, the applied voltage would increase

Figure 9-16 Various voltage protection devices.

Figure 9-17 Varistor.

dramatically, but at the same time the resistance of the varistor instantly drops. A spike of about 150 volts (which is a typical threshold) will decrease the varistor's resistance to the point of creating a virtual short circuit across it. The varistor is commonly located across the AC input line, so its own low resistance allows the excessive current flow which will usually destroy it, and quickly open the line fuse. Varistors are also found in such locations as one or more of the following: across the triac (MT1 to MT2), across the primary windings of the high and low-voltage transformers, from the fuse to chassis ground, or from the fuse to the neutral side. The fast-acting varistor will either shunt the spike around sensitive components or "short out" and open the fuse *before* the spike can do its damage.

Finding a burned or blown-apart thermistor on a printed circuit board, such as the one pictured in Figure 9-18, is a sure indication that a spike or surge passed that way. Whether the board works or not, once the sacrificed MOV is replaced, is an indication of how well the thermistor did its job.

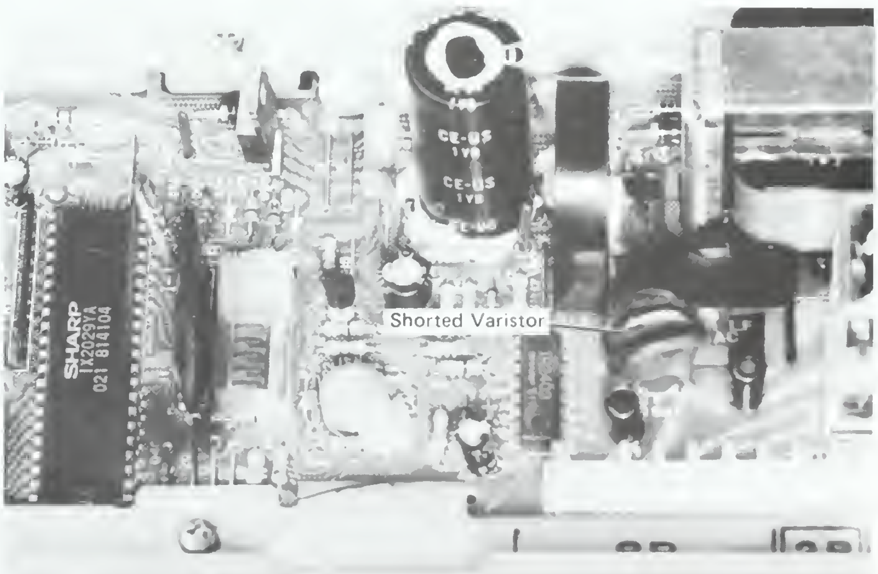


Figure 9-18 Blown-apart varistor on a printed circuit board.

9.8.2 Surge Absorbers

Figure 9-19 Typical surge absorber.

Surge absorbers (Fig. 9-19), also appropriately known as suppressors, protectors, and transient suppressors, work to the same end as the MOV. The difference is that they effectively *absorb* surges or spikes while allowing normal voltages to pass through. Surge absorbers consist of a combination of resistors, capacitors, and coils, or, as shown in Figure 9-20, a gas tube. These components respond to the rate of change of a current or voltage so that a surge reaching a predetermined value will be *dissipated* (or absorbed) across the hot and neutral lines (or bled off to ground, depending upon the configuration), thus preventing it from reaching sensitive oven components.

These surge protector networks may be found variously; connected from the fuse to chassis ground, from the fuse to the neutral side of the line, from one terminal of the triac to ground, paralleling the high-voltage diode to ground, or other protectively strategic locations.

A snubber is a network that comprises a resistor and a capacitor in series. This combination acts to remove voltage spikes caused when the high-voltage transformer powers up, or down.

Surge resistors, as explained in *Section 8.12* are used in conjunction with cook or surge relays, and with some controllers. They serve to limit the initial current flow to the transformer, thereby reducing the damaging effects of sparking or arcing.

Figure 9-20 Gas tube.

9.8.3 PTC Resistor

Figure 9-21 PTC resistor.

Positive temperature co-efficient resistors (PTC), like the one shown in Figure 9-21, are used in conjunction with the start switch in some models to protect against misuse or relay failure. Under normal circumstances, when the PTC resistor is cold, its resistance is low—about 10 ohms. When current flows through the resistor it heats up, and as it does, its resistance increases proportionately. Refer to the simplified schematic of Figure 9-22. With the timer set for a desired cooking time, its contacts "A" to "B" are closed. When the start button is pushed, its momentary contacts close and provide a circuit to the coil of the cook relay as indicated by the dashed arrows. For about the first one-tenth of a second, or as long as it takes for the cook relay to close its contacts, the PTC resistor is in the circuit, limiting the current flow to the transformer. When the cook relay contacts close, the PTC circuit is by-passed and a direct circuit is provided to the power transformer as indicated by the solid arrows.

Suppose, for instance, the operator forgets to set the timer, so the timer contacts remain open. Pushing and holding the start button does not energize the cook relay in this case. However, when the start button is held in, the PTC resistor begins to heat up very quickly. The resistance of the resistor also increases rapidly which reduces the current flow through it. Eventually the current is reduced to the point that the oven goes into a non-operational mode. The oven remains as such for about 5 minutes or until the PTC resistor cools sufficiently. The same would be true if the cook relay or its contacts were to fail; the PTC resistor would not be properly by-passed, thus remaining in the circuit it would produce the same sequence of events.

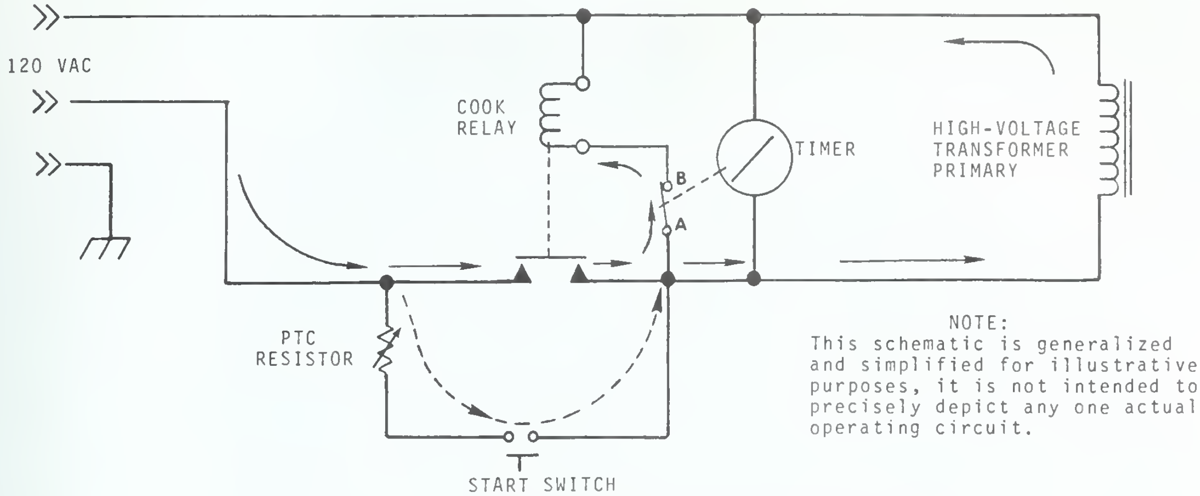


Figure 9-22 Simple PTC resistor circuit.

9.9 FUSES

The line fuse protects the house wiring, provides circuit overload protection for the line and high-voltage circuits, and forms part of the interlock monitor system. The amperage rating of the line fuse varies with the make and model; from 10 amps, in the small 400 to 500-watt-output units, to 30 amps in the large 1400 to 2000 watt units—the most common being 15 amps. A fuse provides protection by means of a thin metal strip or wire through which line current passes. If a circuit draws too much current, the thin metal strip inside the fuse melts and interrupts the current flow. Since most microwave ovens are installed on a circuit already protected by a circuit breaker or house fuse, the main reason for internal fusing is for the interlock monitor function. In cases where the fuse "blows" due to interlock failure, the rupture is so violent that special fuses must be used. These are enclosed in ceramic, bakelite, or wrapped in fiber in order to absorb the blow without shattering the fuse. Figure 9-23 shows some typical fuses which are used in microwave ovens.

In fact, much can be learned as to the cause of a fuse failure simply by examining the manner in which the fuse opened. For example, the way in which the fuse in Figure 9-24 splattered, instead of opening with a small clean rupture, would be a good indication of an interlock related problem. In Figure 9-25, the evidence of

Figure 9-23 Common microwave oven line fuses.

Figure 9-24 "Hard-blown" fuse.

melted solder around the endcap is an indication of a defective fuse holder or the fuse having been insecurely fastened in the holder. When 12 to 15 amps of current flows through an inadequate electrical connection, such as occurs when the fuse is not firmly engaged with the fuse clip, an excessive degree of resistive heat builds up. Eventually, the heat causes the solder connection within the fuse to melt and leach out of the endcap, forming a small bead of solder. Another symptomatic type of fuse failure results in a small clean rupture along the middle of the fuse conductor. This can be caused by a sufficient fluctuation in the line voltage while the oven is operating. These, as well as other fuse-related problems and symptoms, are discussed in greater detail in *Section 14.10.*

Due to their interrelated effects, the monitor switch, interlock switch, and fuse, are all physically mounted as part of the same assembly in some models. This would suggest, when it becomes necessary, that they be replaced as such. Some models, after some time in the field, begin to experience fuse failures for no apparent reason other than the fact that the fuse proves to be of insufficient rating. In these cases the manufacturer usually issues a "service bulletin" advising the use of a higher rated fuse. For example, in February of 1984 *Amana* instructed that a 20 amp fuse be used to replace the original 15 amp fuse, especially in cases where the cause of a fuse failure could not be identified. This increased the reliability of the units involved, and yet maintained the integrity of the interlock monitor circuit. *Litton* has done the same with certain commercial models, increasing the physical size of the fuse as well. Increasing the physical size of the fuse and fuse holder increases the heat dissipating capabilities of the assembly, thus improving its reliability. Other such undue and intermittent fuse failures have also led manufacturers to issue field modifications which relocate the fuse, either physically, or electrically, or both. In each and every case, however, modifications should never be made without first contacting the respective manufacturer for their verification, approval, and instructions.

Unless otherwise advised by the manufacturer, the fuse should always be replaced with one of an equal rating. **NEVER DEFEAT THE FUSE.** Even when troubleshooting, it is better to use a temporary fusing arrangement, such as the "fuse

Figure 9-25 Melted fuse.

saving device" described in *Section 5.4,* or even to sacrifice a relatively inexpensive fuse, rather than risk the possibility of the oven leaving your care with the fuse "jumpered out".

9.10 MAGNETRON PROTECTION AND FAILURE DETECTION

Many commercial microwave ovens manufactured by *Sharp Electronics* utilize two rather physically large fuses in the high-voltage circuit. These commercial ovens employ two magnetrons, each with their respective high-voltage systems (the filament transformer is common to both systems), the components of which are protected, in each case, by a *high-voltage fuse* (Fig. 9-26). Each fuse is connected, in its respective system, between the high-voltage output of the transformer and the high-voltage capacitor. These fuses, generally rated at 0.6 amps at 5,000 volts, will open in the event of a shorted magnetron (anode to cathode), a shorted capacitor, diode, or other short in the high-voltage circuit. When replacing one of these fuses, the coil spring—visible through the fuse glass—should be facing downwards.

Additionally, many *Sharp* commercial units are equipped with *magnetron failure detection circuits.* The oscillation of each magnetron is checked by its respective detection circuit which, in each case, monitors the plate current of the tube. Any significant fluctuations in the magnetron's oscillation, denoted by a change in its plate current, will trigger the detection circuit and illuminate a small indicator lamp (LED) on the front panel. The lamp (when lit) gives visible indication of a magnetron circuit failure and makes the operators aware of the need for service. It also explains why they are eating *lukewarm* chili.

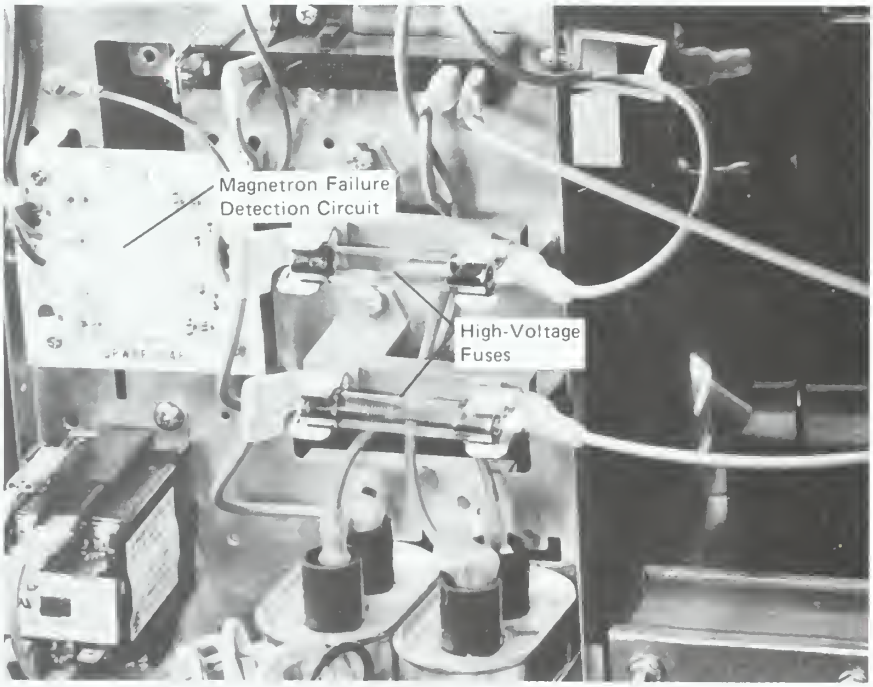


Figure 9-26 High-voltage fuses.

Microwave Containment Components

chapter 10

10.1 INTRODUCTION

Microwave energy that is generated by the magnetron tube must be channeled into and contained within the cooking cavity of the microwave oven. Microwave containment components are constructed of various materials that either reflect, transmit (allow to pass through), or absorb the energy, depending on the function. The oven cooking space or cavity is a reflective enclosure which is constructed from stainless steel, painted metal, or aluminum. The microwave energy is transferred to the cavity through a hollow metal enclosure called a *waveguide*. The *door leakage safety system* provides access to the cooking cavity, and yet during the cook cycle, seals off would-be escaping energy by both reflection and absorption. In order to gain a general concept of the behavior of microwave energy in a confined area, a few basic principles concerning the *cavity resonator* should be considered.

10.2 THE COOKING CAVITY

The oven cooking enclosure is actually a *cavity resonator;* in other words, it is designed to *resonate* the microwaves radiated from the magnetron. From the standpoint of resonance, electromagnetic waves may be compared in a general way to sound waves. Therefore, the way in which an oven cavity resonates may be illustrated in those terms: Anyone who has ever had the experience of playing a note on a piano and hearing an object across the room, perhaps a wineglass, vibrate and produce the same sound has heard the results of *resonance*. The wineglass manifests sympathetic vibrations to the sound waves produced by the piano string because the resonating characteristics of the glass are the same as those of the piano string. In other words, the wineglass is in *tune* or in *resonance* with the sound wave produced by the piano string.

In the same way, the cooking cavity of a microwave oven is proportioned to be

in "tune" with the resonant characteristics of the microwaves, so it is a *resonant cavity*. That is, a space completely enclosed by conducting walls that are able to contain oscillating electromagnetic fields and possesses resonant properties. Microwave energy introduced into the resonant cavity bounces back and forth between its walls. At the resonant frequency the reflected waves reinforce each other, producing consistent and strong oscillations. Drawing on the illustrative sound wave once again: In a room with smooth hard surfaces creating good acoustics, the sound of a series of sharp noises would reflect from wall to wall with very little decrease in amplitude at each reflection. If the dimensions of the room were such that the sound waves reflected off of the hard surfaces so as to travel directly back toward the source of the sound at the same velocity and phase of the oncoming sound waves, the effect would be *standing waves.* These waves, traveling in opposite directions but at the same velocity and in phase, would combine and, in effect, *stand* still. In areas where standing waves occur, the sound would be much louder because they reinforce each other. The room in this example is proportioned to exhibit resonance. In a similar way, the cooking cavity of a microwave oven is proportioned with the energy output of the magnetron tube to exhibit resonance, thus producing a uniform electromagnetic wave pattern within the cooking space.

10.3 THE COOKING SHELF

The bottom or floor of the cavity is usually drawn into the form of a well as shown in Figure 10-1. This enables the glass tray, carousel, or ceramic shelf to hold the food at about 1 to 1 ¼ inches above the cavity floor. Whether sealed in or removable, the shelf is virtually transparent to microwaves. So the energy passes through the shelf and reflects off the bottom, back up into the food. To the microwaves the food is suspended in mid-air, so, they can penetrate it from all sides with uniform intensity.

The clear glass trays used in microwave ovens are made from specially processed safety glass which will absorb certain amounts of RF energy and are tempered

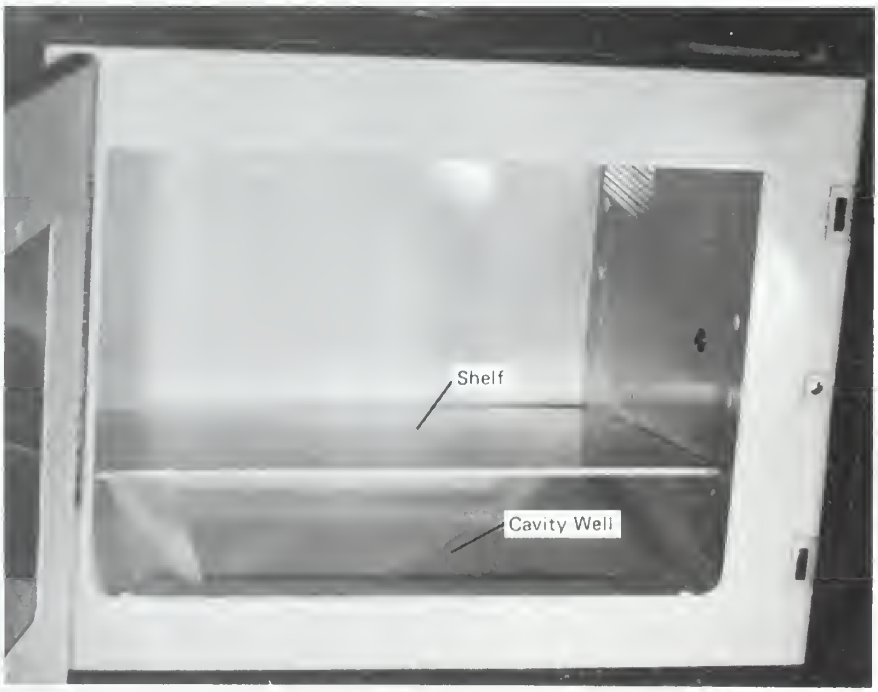


Figure 10-1 Cavity well.

for greater impact strength. This borosilicate glass has special properties making it highly heat resistant and enabling it to absorb RF energy, in the event of prolonged no-load operation (sometimes to the point of glowing red), without breaking. Also, this glass is much more pure than ordinary glass; a flaw in glass that is exposed to microwave energy could cause the glass to explode.

Ceramic shelves, usually sealed in with an RTV sealant, are made of a special ceramic called *Pyroceram* (range cook-tops are made from the same type of material). These shelves also absorb certain amounts of RF energy, so in the event of no-load operation they too act as a *dummy load* and absorb enough of the energy to minimize arcing, leakage, or reflected energy. Refer to *Section 15.5* for procedures regarding the removal and replacement of sealed-in shelves.

10.4 THE WAVEGUIDE

Normally electric current flows *through* a conductor. But at the high frequency of microwaves the current flow is more on the surface of the conductor. Waveguides are just what their name indicates, they guide or transport electromagnetic radiations of microwave proportions from one point to another. Waveguides are hollow tubes constructed from conductive material and, in microwave ovens, are generally rectangular in shape as shown in Figure 10-2.

As Figure 10-3 illustrates, the energy is radiated from the antenna of the magnetron tube and *propagates* (or travels along) through the length of the waveguide by the interaction of its electric and magnetic fields, reflecting from wall to wall in a zig-zag pattern. Remember, electromagnetic energy consists of electric and

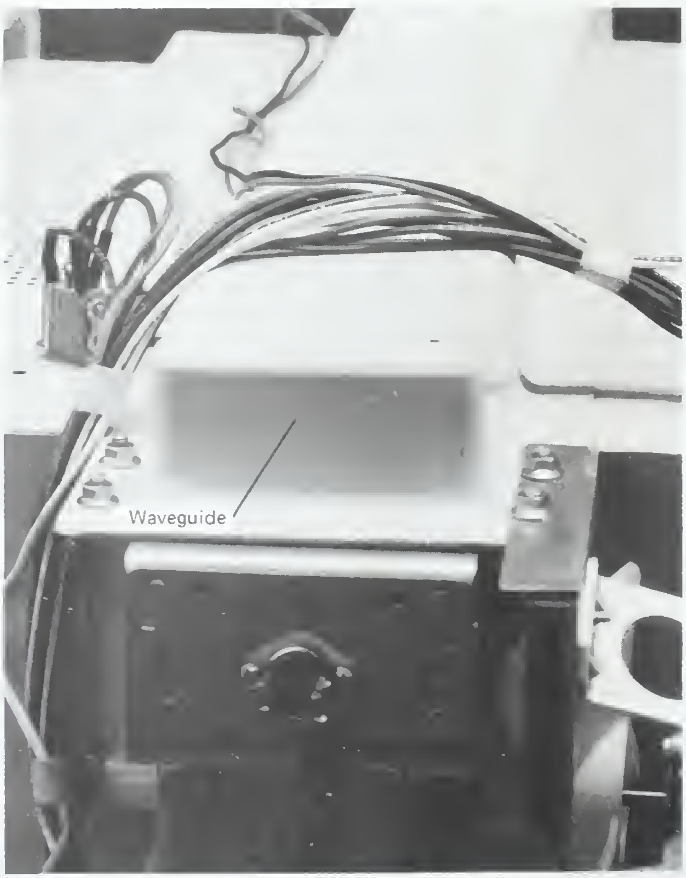


Figure 10-2 Waveguide.

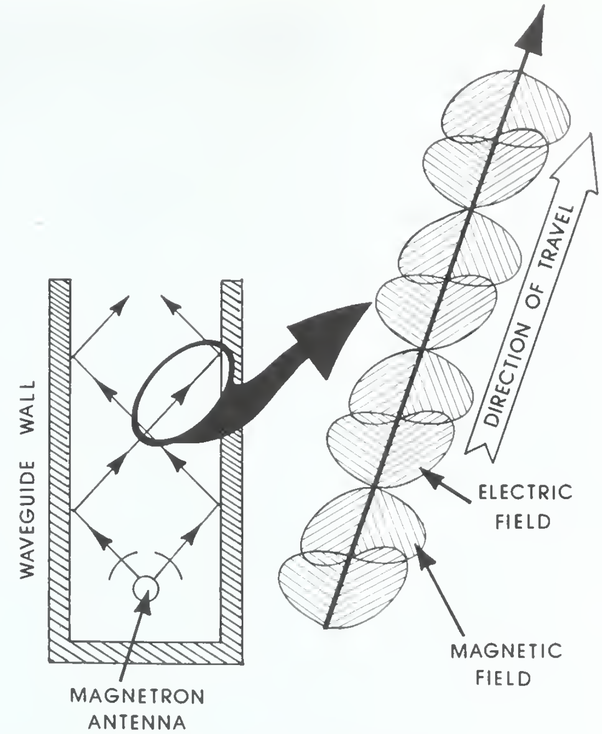


Figure 10-3 Electromagnetic energy traveling through a waveguide. (Courtesy of Michael S. Wagner)

magnetic fields that are at right angles (90°) to each other and right angles to the direction of travel. To simplify the illustration, only the direction of travel is indicated by the lines and arrows. The wavefronts are at right angles to the direction of travel as shown in the close-up of one section of the wave.

Waveguides are not always perfectly impedance-matched to their load, which in a microwave oven is the resonant cooking cavity. Therefore, impedance-changing *tuning stubs* are placed in the waveguide to match the waveguide to the load. In microwave ovens these tuning stubs are usually posts or screws (Fig. 10-4) which are made from conductive material and that project partially into the waveguide. The tuning stub is located in a *null* area of the radiation pattern so the magnetron does not "see" it, and has the effect of introducing capacitance into the waveguide. Waveguide impedance matching is necessary to minimize reflected energy caused by an impedance mismatch between the waveguide and the load.

A waveguide that is warped, bent, or obstructed in some way, will create severe attenuation of the energy, affecting the cooking capabilities of the oven, and possibly causing arcing, reflections, or excessive RF leakage.

10.5 THE DOOR LEAKAGE SAFETY SYSTEM

Although the physical designs may vary from one model to the next, the same basic principles are employed in "choking off" escaping microwaves. To keep the explanation simple, just one representative door seal system will be examined and the principles involved may then be applied to other systems as they are encountered.

Refer to the sectional view in Figure 10-5. A typical door leakage safety system comprises three different types of seals: the *capacitive seal,* the *choke,* and the *secondary seal.*

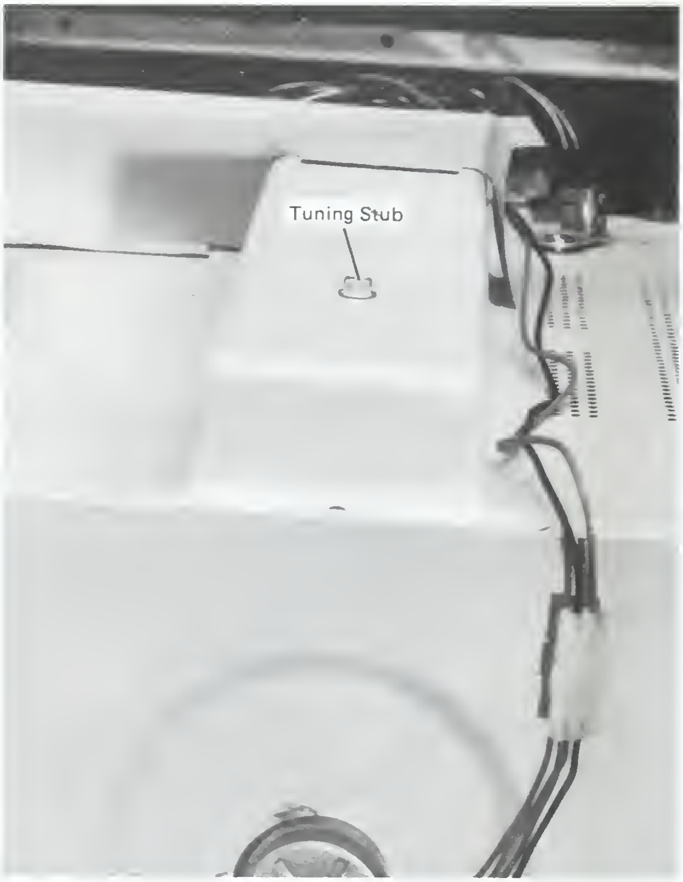


Figure 10-4 Tuning stub.

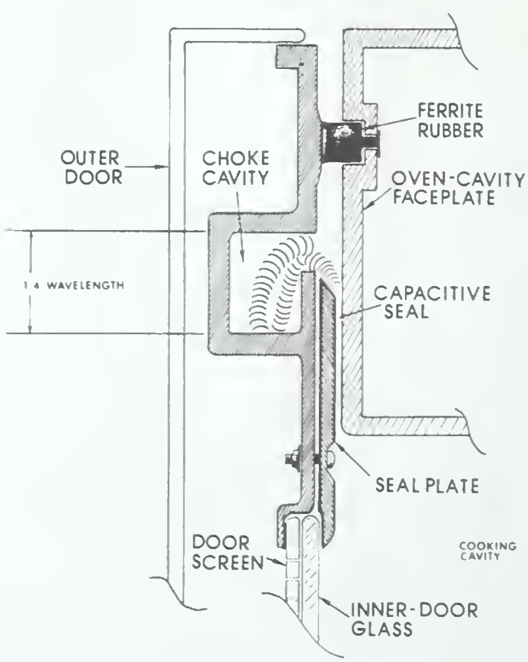


Figure 10-5 RF containment system in a typical door.

The capacitive seal is formed by the snug fit between the *seal plate* and the facing of the oven cavity.

The choke is the primary seal of the system. The choke is formed by an opening or channel that is built into the door surface, and extends around its periphery (in many models the choke cavity is contoured into the faceplate of the cooking cavity). This channel or choke cavity is proportioned to be one-fourth of the wavelength of a microwave (remember one wave length equals approximately 4.7-inches). As next described, this characteristic creates a trap for escaping microwaves that is virtually inescapable.

As shown in Figure 10-5, microwaves escaping the clearance between the door and the oven faceplate (capacitive choke) will enter the choke cavity, reflect off the inner wall, and travel back out. Since the choke cavity is one-fourth the length of a wave, each wave travels a quarter wavelength going in and a quarter wavelength going out—a total of one-half of a wavelength. A sampling of the waveforms present at the entrance to the choke cavity would resemble those in Figure 10-6. The incoming waves (A) can be compared with the outgoing waves (B) by superimposing waveform "A" over waveform "B". The resulting waveform "C" shows that the waves cancel each other out. This canceling effect "chokes off" any further leakage from the clearance between the door and the cavity facing.

Part of the choke assembly in many models is a *choke filler*. This plastic-like material (polypropylene is commonly used) is formed to either fill the inside of the choke cavity or cover it. This filler (or covering, whichever the case may be) is there to keep the interior of the choke cavity clean and help to maintain its precise shape. It is important to never operate an oven with this removed, because, while most choke fillers are transparent to microwaves and serve only the purposes mentioned above, some are designed to absorb low levels of microwave energy as part of the secondary seal.

The secondary seal is in the form of gaskets that are attached around the periphery of either the door, or the opening to the cooking cavity (as in Figure 10-5). These gaskets are made from, either strips of ferrite rubber, or vinyl which has been impregnated with carbon black. In either case, they are designed to absorb low levels of microwave energy that may elude the choke.

It should be noted that steam or vapor may escape from around the door. Also, light reflections around the door or outer case may be visible. This is because the door gasket prevents microwave leakage by absorbing spurious harmonic fre-

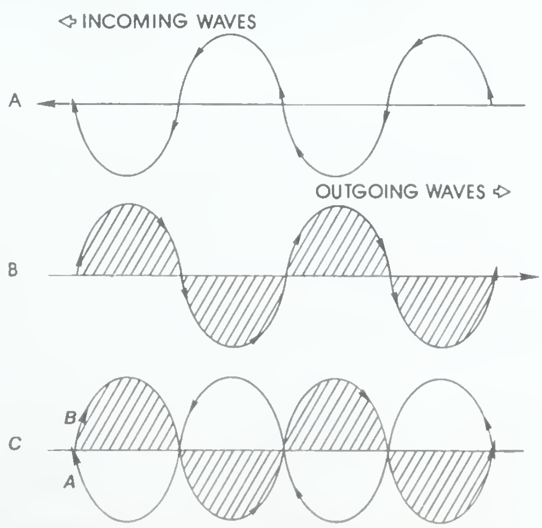


Figure 10-6 Canceling effect of the choke.

quencies and it does not have to be airtight (or "light-tight") to accomplish this. Therefore, the door seal does not form a vapor seal. The oven light is located outside the oven cavity and can reflect light out around the hinge, door, outer case, and lamp access cover. Therefore, the occasional appearance of moisture around the oven door (especially when cooking foods with a high moisture content or under humid conditions), small areas of visible light, or the movement of warm air around the door, are all normal conditions and do not necessarily indicate that the oven is leaking microwave energy.

The door screen makes it possible to view through the oven door to the interior of the cooking cavity (Fig. 10-7). This is a perforated metal screen in which the diameter of each perforation is quite small in relation to the size (wavelength) of a microwave. Therefore, microwaves being too large to escape through the holes, react as though this screen were a solid wall, and simply reflect back into the cooking area. It should be noted however, no seal is absolute, so viewing through the door from a close range should be avoided, unless doing so momentarily for troubleshooting purposes and wearing protective glasses. *(Section 5.4* describes "homemade" protective glasses).

Various problems associated with doors and other containment components, as well as related servicing procedures, are discussed in *Chapter 15.*

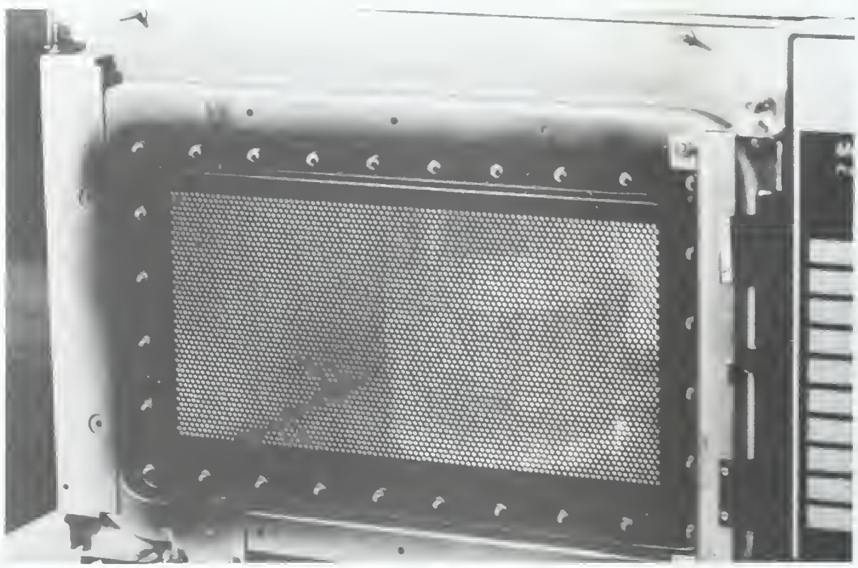


Figure 10-7 Door screen.

Cooling and Energy Dispersion Systems

chapter 11

11.1 INTRODUCTION

Essential to the proper operation of a microwave oven are the cooling and the stirrer systems. Although the primary purpose of the cooling system, which will be discussed first, is to cool the magnetron assembly during operation, it also serves other functions as well. The stirrer system (or food rotation mechanism in some models) provides a means to allow microwave energy to penetrate the food from all sides in a uniform cooking pattern. As with components previously discussed, the cooling and stirrer systems vary considerably from one model to the next. However, again, the basic principles involved are the same and may be applied to all systems. Whereas significant differences will be discussed more extensively, the basics will be illustrated by means of representative systems.

11.2 COOLING SYSTEMS

Heat generated within the magnetron tube during operation must be removed to prevent an overheating condition. This is accomplished by the forced air generated by the *blower motor.* The blower motor, also referred to as the *fan* or *cooling motor,* drives either a squirrel-cage-type wheel, or a fan blade. Figure 11-1 shows three typical blower motors and Figure 11-2 depicts two *transmotors.* A transmotor is a blower motor and a low-voltage transformer combined into one unit. The blower fan directs cool air through the cooling fins of the magnetron, then the air is ducted into the oven cavity.

The duct work in some models may appear to be only insignificant cardboard, but its proper positioning is vital to insure proper air circulation. Some air ducts are positioned so as to remove moisture from the area of electrical components, while others divert portions of air to cool electrical components, such as the high-voltage transformer. And, in some models, air coming off the magnetron must be ducted

Figure 11-1 Typical blower assemblies.

into the cooking cavity with sufficient velocity to create a swirling action that turns an air-driven stirrer blade, or antenna.

Air circulating from the magnetron and into the cooking cavity is then exhausted out the top, front, or back—depending on the model. As the air moves through the cavity, it provides ventilation which removes steam or vapors as they are given off by the cooking food. This prevents moisture build-up around the door and within the cavity.

The air intake is usually located in the bottom, or the back of the oven chassis. Many commercial units are equipped with an air filter which prevents grease or dust from collecting and blocking the air flow passages within the oven. However, a dirty filter, or any other obstruction of the air intake, will inhibit the air circulation, causing the unit to overheat and eventually render itself inoperative.

Some over-the-range type models or combination microwave-convection models use two fans or blowers; one provides circulation and ventilation, and the other cools the magnetron tube.

Models that feature convection cooking also have a *convection fan* which forces air across a heater coil. This fan, either air, belt, or direct motor driven,

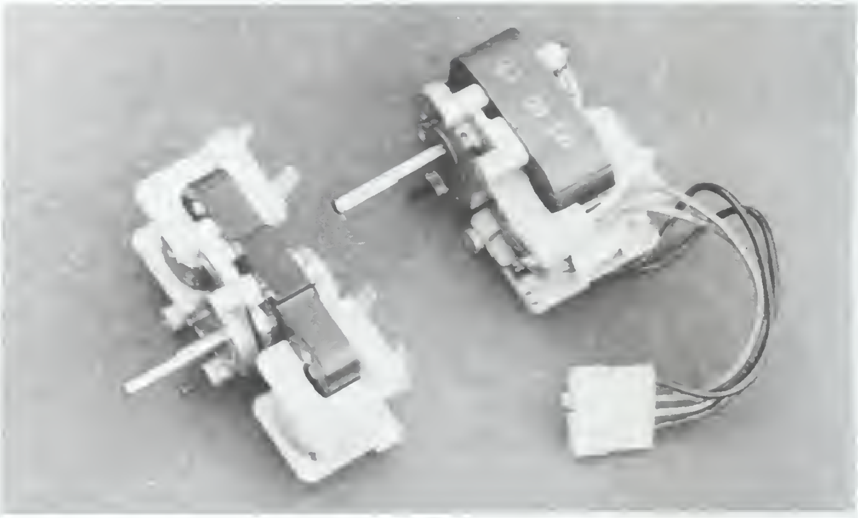


Figure 11-2 Typical transmotors.

creates a high-speed circulation of hot air that swirls around the food providing fast conventional cooking and browning. Once exhausted from the oven cavity this heated air does not leave the oven, but is forced back across the heating element and re-circulated back into the oven cavity in a continuing cycle. So in convection cooking the food is not heated directly by the heating element, but is heated by the forced circulation of hot air.

For added protection, especially in models that are built-in, many—if not most—models are constructed with a thermal fuse embedded within or near the motor windings (Fig. 11-3). If the motor experiences a physical bind, a short in its windings, or some other failure that causes it to overheat, the non-resetting thermal fuse will open. In most circuit configurations this will, sooner or later, result in total oven shutdown. When this occurs it is necessary to replace the entire motor assembly, at which time the servicer should be alert to factors that possibly could have initially contributed to or caused the overheated condition of the blower motor. As a temporary *emergency* measure (such as is occasionally called for when servicing commercial units), it is possible, in some cases, to carefully replace this internal thermal fuse and thus restore oven operation. Remember though, this is only a temporary means to put the unit back in operation until a replacement blower motor assembly can be obtained and installed.

Additional problems that are associated with cooling systems, the resulting symptoms, and the proper corrective measures, are considered at length in *Sections 16.2* and *16.3*.

11.3 STIRRER, FOOD ROTATION, AND ENERGY DISPERSION SYSTEMS

In order to achieve a uniform temperature rise within the food to be cooked, either the energy must be evenly dispersed, or the food must be evenly rotated through the energy. In various makes and models of microwave ovens there are several different ways, with varying results, in which this is accomplished.

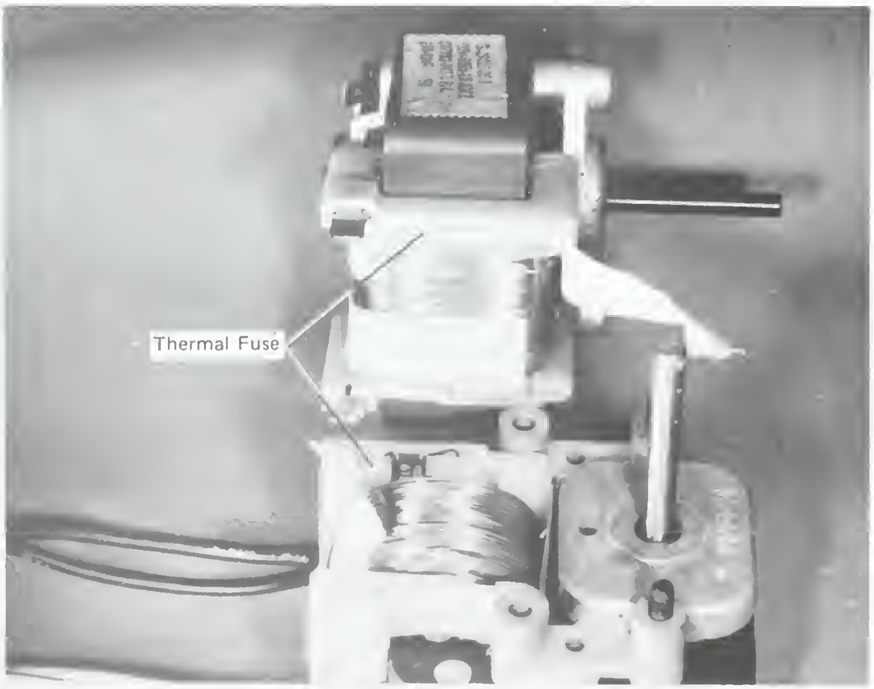


Figure 11-3 Thermal fuses embedded within the motor windings.

Probably the most common method of "stirring" the energy is by a metal *stirrer blade.* Figure 11-4 shows a number of different types of stirrer blades; some are belt or motor-driven and others are turned by air. In simple terms, the effect of the high-speed energy hitting the slowly rotating metal blades is much like water being sprayed into the blades of high-speed fan. The energy, like the water, is effectively dispersed throughout the surrounding area. The stirrer blade is also referred to as a *mode stirrer,* which gives rise to a slightly more technical explanation: Energy emitted from the magnetron radiates through the waveguide and into the cooking cavity. In the absence of a stirrer system, the microwaves enter directly into the cavity with some of the energy being absorbed and some reflecting around the cavity until it is absorbed. The resulting intensity of the microwave field along the cavity walls is very low, and within the expanse of the cavity, severe *energy mode differences* are being created by *standing waves.* Recall that in the area of a standing wave the energy has the effect of reinforcing itself, so standing waves would create energy "hot spots" (peaks) and the surrounding areas, by comparison, would be energy "cold spots" (nulls). This difference in oscillation modes results in unacceptably uneven cooking. To prevent these energy mode differences the slowly rotating, metallic fan-like blades of the *mode stirrer* deflect and disperse the RF energy, effectively moving the peaks and nulls to all parts of the oven cavity in a relatively uniform pattern.

Stirrer blades are usually located in the ceiling area of the cavity, and as mentioned, are driven by a motor, by swirling air from the blower motor, or by a belt and pulley connected to the blower motor, depending on the model.

Motor-driven blades are generally attached to the motor shaft by a slip clutch type of arrangement which allows the motor shaft to come up to speed relatively unencumbered, with the blade soon catching up. This makes it possible to use a smaller low-torque motor for this purpose. Figure 11-5 illustrates a typical stirrer assembly.

Most models use just one blade which provides adequate heating uniformity usually. But in many cases, such as with larger or more delicate dishes, satisfactory results are possible only by rotating the food (by 180°) at least once during the cooking cycle. Wind-up and battery operated turntables that rotate the food during the cooking cycle have improved the cooking performance of many a one-stirrer-blade oven. The original "meal-in-one" models manufactured by *Litton* use two motors and blades, one on each side of the oven cavity (Fig. 11-6), each rotating at

Figure 11-4 Various types of stirrer blades.

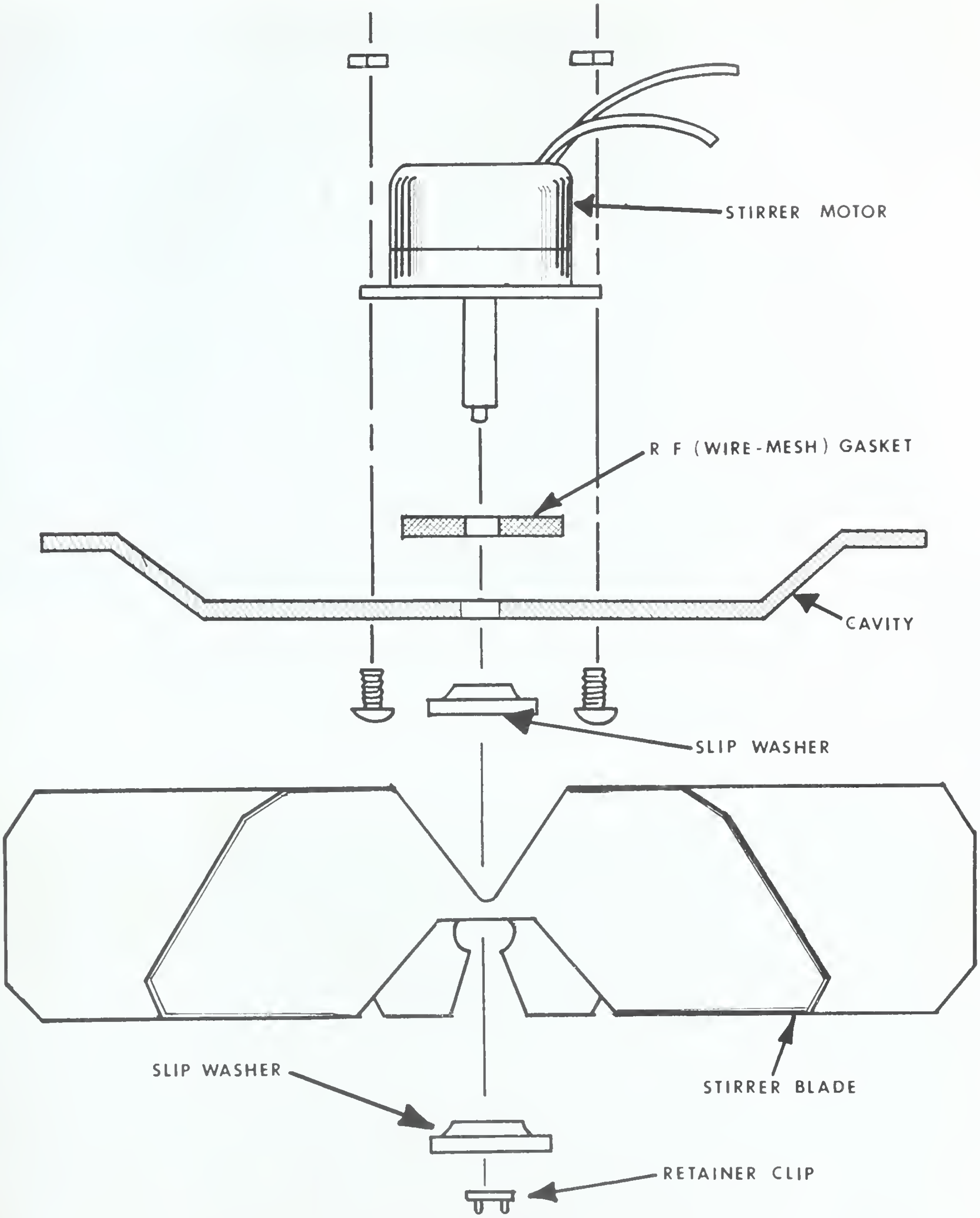


Figure 11-5 Typical stirrer assembly. (Courtesy of Michael S. Wagner)

different speeds. In these models the energy is dispersed into the cavity from each side resulting in an above-average cooking pattern that cuts down on rotation and allows the use of a metal rack. The rack was designed to allow an entire meal to be cooked at the same time by, in effect, dividing the cavity into two compartments. The area above the rack receives a higher concentration of energy for food with greater density. The area below the rack, where lesser amounts of energy "filters" though, is for cooking more sensitive items. With practice, it works. Later versions

Figure 11-6 Side-mounted stirrer blades.

of the "meal-in-one" concept used two air-driven blades balanced on support bars in the top of the oven cavity.

11.4 CAROUSEL OR TURNTABLE SYSTEMS

Driven, either by its own separate motor, or by the blower motor through an arrangement of gears or belt and pulley, the turntable rotates the food at a constant speed within and through the energy field thus achieving a consistent and uniform rate of cooking. Rather than the energy being dispersed, the varying effects of energy mode differences are evenly distributed as the food slowly rotates through the peaks and nulls of the RF energy field.

The obvious advantage of this type of system is the uniformity with which the food cooks as a result of its constant rotation through the energy. The disadvantages are not quite as obvious: The food product to be cooked must be within a size and shape that will allow for it to make a complete rotation without hitting the door or cavity walls. Additionally, although complaints of *uneven* cooking are rare, they do occur, and whereas the cooking pattern can be adjusted in stirrer-type models, in units that rely of the rotation of the food the energy pattern—such as it is—is fixed and can be altered only by changing the magnetron tube. *(Tappan* has introduced a new model that offers both a turntable *and* a stirrer system.)

Figures 11-7 and 11-8 show two of the more common methods of connecting the turntable to its means of motivation through the floor of the cavity. In Figure 11-7, a coupling extends through an opening in the cavity floor where a slot in the coupling fits, first over a rubber spacer, then over a pin or key in the shaft of a relatively hefty motor. Figure 11-8 illustrates the use of a rotating magnetic field that, while it has its disadvantages, it does manage to turn the tray with no physical connection, eliminating the need for a worrisome hole in the bottom of the cavity.

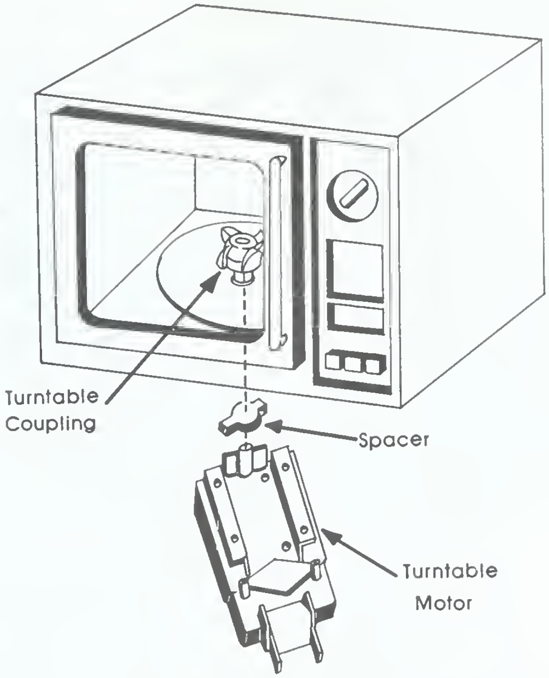


Figure 11-7 Turntable motor and coupling. (Courtesy of Michael S. Wagner)

Figure 11-8 Magnets mounted in a belt-driven pulley assembly which rotates the turntable.

11.5 THE ROTATING ANTENNA

A basic antenna must have a definite length and a uniform width, these exact dimensions being determined by the frequency of the energy to be transmitted or received. The design of rotating (or moving) antennas used in different models of microwave ovens varies to some extent but basically comprise one, two, or four conductors or *radiators* (Fig. 11-9). Each radiator intercepts or receives energy as it is coupled from the waveguide, and then transmits the microwave energy into the cavity. In some models, mostly *Amana,* the four-conductor antenna is suspended at one-quarter of a wave length (one wave length equals about 4.7 inches) from the top of the oven cavity by a polypropylene mounting assembly. Just below the antenna is a protective cover called a grease or splatter shield. Raised air guides, which extend from the upper surface of the grease shield, cause the circulating air, supplied from the cooling motor, to swirl around the antenna. Plastic fins on the antenna assembly catch the swirling air, providing turning power for the assembly so that the four [half-wave length] radiators beam down a rotating shower of microwave energy in a controlled uniform pattern.

In other units the moving antenna is mounted in a recessed area beneath the cooking shelf. Microwave energy is fed through the waveguide (which extends along the underside of the cavity) and collected by the belt-driven rotating antenna. As the antenna assembly turns, it radiates the energy *up,* through the shelf, and into the cooking cavity in the same controlled rotating pattern. Presently, brands that use this type of system include: *Amana convection models, most Quasar* models, and, as pictured in Figure 11-10, some commercial *Panasonic* models.

Checks, defects, and repairs involving the energy distribution components are considered in *Section 16.4*.

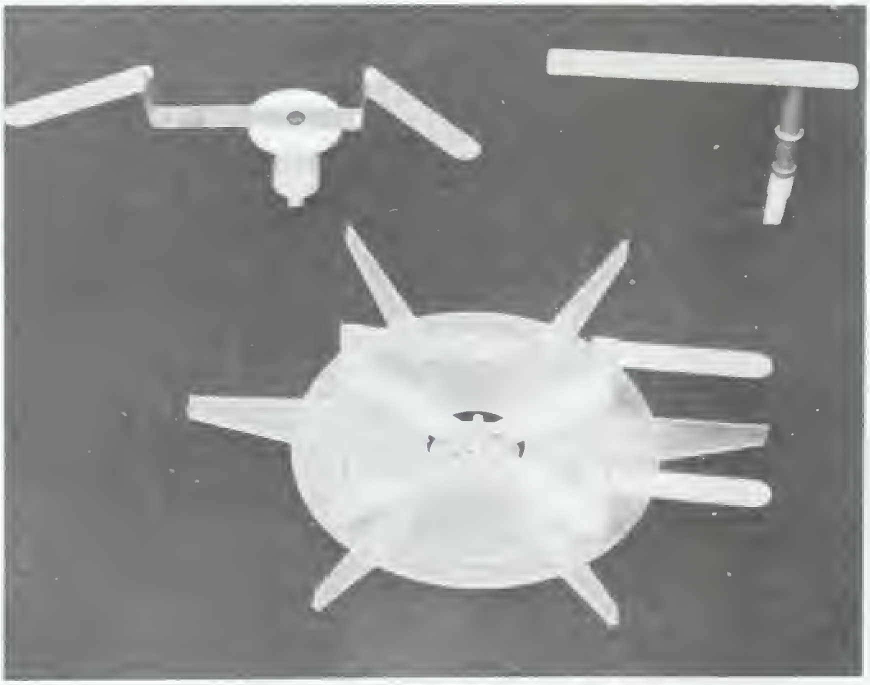


Figure 11-9 Typical antenna assemblies.

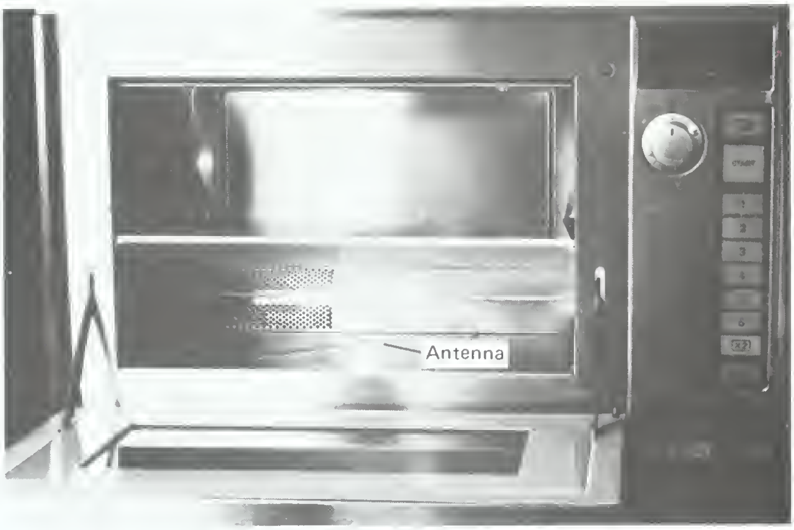


Figure 11-10 Commercial unit with a floor-mounted antenna.

11.6 STIRRER AND WAVEGUIDE COVERS

To keep the aforementioned antenna and stirrer blade compartments clean, and to keep fingers away from sharp edges, a protective cover is used. These covers are commonly referred to as *stirrer covers, grease shields,* or *splatter shields,* and are less commonly referred to in a variety of other terms. Stirrer covers, such as the one shown in Figure 11-11, are made of a hard and tough thermoplastic resin called polypropylene which is resistant to fire, moisture, grease, oils, and high temperatures. Others are made of glass or ceramic similar to the cooking shelves discussed earlier. Without the benefit of these covers, grease and food particles would soon

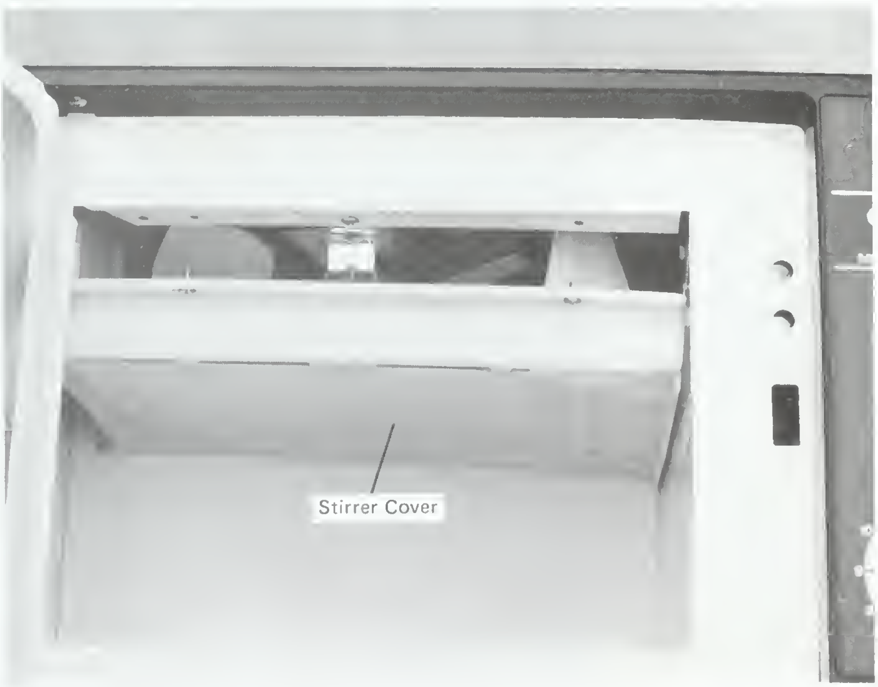


Figure 11-11 Stirrer cover lowered to reveal stirrer assembly.

lodge in the hard-to-clean cracks and crevices of the stirrer or antenna compartments. After prolonged or repeated exposure to microwave energy, these trapped particles burn to the point of carbonizing, consequently causing arcing.

Models that use the turntable need only protect the opening where the energy enters the cavity from the waveguide. *Waveguide covers,* such as the one shown in Figure 11-12, fit neatly over the waveguide opening and provide protection in the same way and for the same reasons as do the stirrer and antenna covers.

Section 16.8 details the various problems, the accompanying symptoms, and proper corrective measures associated with these stirrer, antenna, and waveguide covers. The frequency of one common problem merits its brief mention at this point: Small amounts of grease become trapped around or under the edges of the cover, in particular, the waveguide cover. Repeated cooking soon causes the film of grease to carbonize and arcing occurs, resulting in a burned spot similar to the one pictured in Figure 11-13. The crackling flash of light caused by the arcing usually

Figure 11-12 Typical waveguide cover.

Figure 11-13 Waveguide cover burned from arcing.

results in the prompt unplugging of the oven, and an anxious call for repair. After carefully cleaning out residual grease, sanding out *all* traces of carbon, and touching up the paint, the servicer must then replace the cover.

11.7 BAFFLE SYSTEMS

Models that rely on a system of baffles to diffuse the energy as it enters the cavity are all but obsolete. Except for the advantage of having no moving parts, this type of system really serves only to baffle those who do not like their food striped.

Component Tests, Failures, and Corrective Actions

Part 4

Having studied how and why the components of a microwave oven operate, it becomes easier to understand how and why these components sometimes fail to operate. Knowing the characteristics of a part helps in recognizing the symptoms that are associated with the failure of that part.

Part 4, consisting of *Chapters Twelve* through *Sixteen* describes the various component failure modes with the resulting symptoms: visual, audible, and odorous. Part 4 parallels Part 3 in its arrangement of components into respective sections. The *failure,* its effects, symptoms, and cause (if applicable) is then discussed. In each case the appropriate testing and troubleshooting techniques are accompanied by the proper corrective procedures. Threading their way through the entirety of Part 4 are many valuable hints and "tricks of the trade" to enhance the technician's troubleshooting and servicing ability.

High-Voltage Component Testing, and Failure Modes

chapter 12

12.1 INTRODUCTION

Finding the trouble in a microwave oven begins by determining the general area of the problem. Then, by analyzing the nature of the symptoms, the most and least likely suspects can be isolated and separated. The components that are *least* likely to cause the displayed effects can be eliminated for the time being, while the more probable candidates can then be systematically checked using the applicable procedures from the following test methods.

12.2 ISOLATION TEST

First, though, how do you know where the problem area is based solely on the symptoms? For example: is a complaint of "no heat" the result of a defective interlock switch or a defective magnetron, an open triac or a shorted diode? If a diligent inspection fails to reveal any obvious problems, the answer is to then divide and conquer: DIVIDE THE UNIT INTO TWO SECTIONS—THE CONTROL SECTION AND THE HIGH VOLTAGE SECTION—WITH THE DIVIDING POINT BEING THE PRIMARY TERMINALS OF THE HIGH VOLTAGE TRANSFORMER. (See Fig. 12-1).

Electrically, all components before the transformer primary winding form the control section. Components that are electrically located after the transformer primary winding, including the transformer itself, comprise the high-voltage section. The section in which the problem lies is determined by whether or not there is primary voltage available to the high-voltage transformer during a cook cycle. If there is proper primary voltage, the control section is operating normally, which puts the fault in the high-voltage section. On the other hand, the absence of primary voltage points to the control section as the problem area. The first test in this series outlines the procedure for isolating the problem area in this manner.

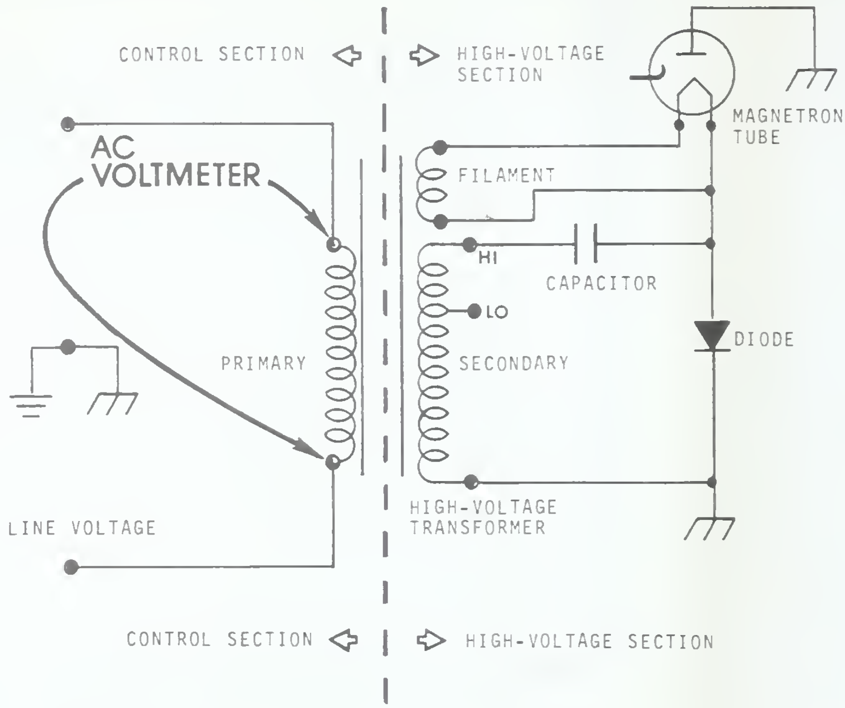


Figure 12-1 Isolate the problem to either the high-voltage section or the control section.

Dual magnetron commercial units must at times be further divided in order to evaluate the operation of each individual magnetron as well as its supporting high-voltage system. The high-voltage systems are isolated by disabling one side and then operating the oven in this semi-operational condition while checking the non-disabled side. Either system may be disabled first, unless one side in particular is under suspicion. Before proceeding, observe the safety listed below. Disable the individual high-voltage systems by disconnecting one or both of the leads from the HV transformer primary of that system. Insulate the disconnected wires to avoid any shorts. Put the oven into a full-power cook operation and make an output power check of the non-disabled side. Having established the functional status of the one side, repeat the procedure for the other side.

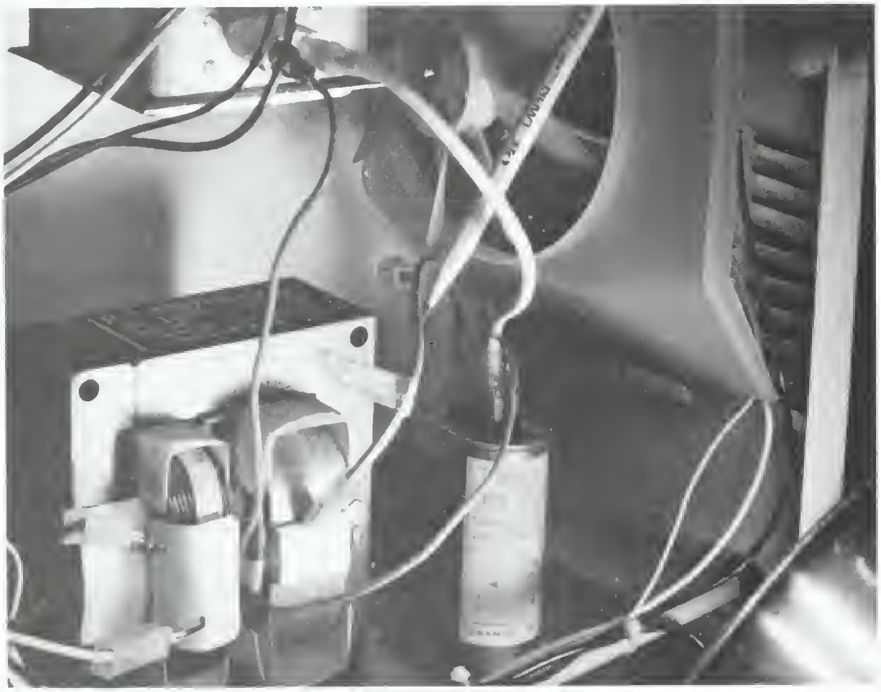
Repeated throughout this section are warnings regarding safety. It is imperative that these precautions be strictly observed. Read each procedure thoroughly before performing the test. When making operational tests use clamp type devices (i.e. alligator clips) to attach the meter leads.

WARNING: HIGH VOLTAGES ARE PRESENT DURING OPERATIONAL CHECKS, USE EXTREME CAUTION. DO NOT TOUCH COMPONENTS OR WIRING WHILE THE UNIT IS OPERATING.

12.2.1 Isolating the Problem Area

1. Unplug the unit and remove the outer cover (also referred to as case or wrap).
   NOTE: Some outer covers (or cabinets) are not that easily removed unless certain procedures are followed. *Appendix II* reveals some of the secrets of outer case removal.
2. DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

3. Locate the primary terminals of high-voltage transformer. If the positioning of the transformer is such that the primary terminals are not easily accessed, use the schematic or wiring diagram to find electrically equivalent test points.
4. Identify and remove the *high-voltage lead.* This is the wire that is connected at one end to the high-voltage secondary tap of the high-voltage transformer as shown in Figure 12–2. (Some models have more than one HV tap, so note from which tap the HV lead is removed.) The other end of the high-voltage lead is the lone connection (besides the bleeder resistor if



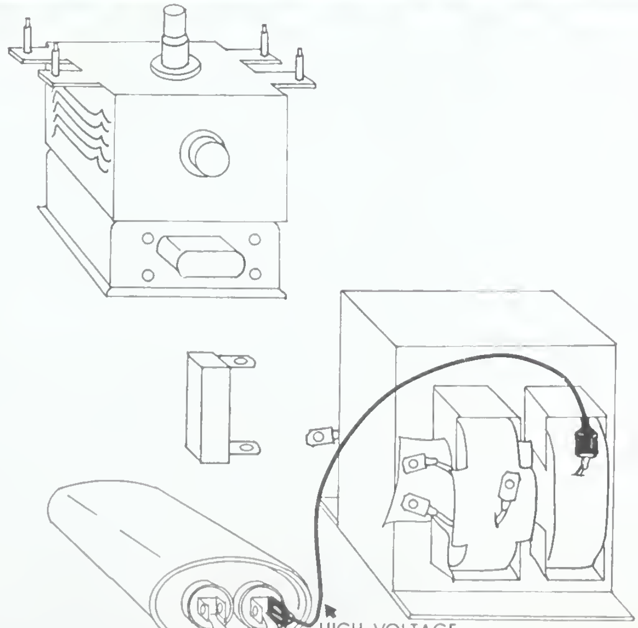


Figure 12–2 Identify and remove the high-voltage lead.

present) on one terminal of the HV capacitor. In other words, disregarding the possible presence of an external bleeder resistor, one terminal of the high-voltage capacitor has connected to it a single wire—it is that single wire that is to be removed. Attached to the other capacitor terminal are several wires: a lead from the diode, and wires from the filament winding of the transformer. the magnetron, or both. Having positively identified the high-voltage lead, disconnect both ends and remove the wire completely from the oven.

5. Leaving the harness leads connected to the primary of the transformer, attach the meter leads—with alligator clips—to the transformer's primary terminals, or to points that are electrically the equivalent.
   A. Briefly switching the meter to a resistance scale at this point will verify good meter lead connections. Be sure to switch back to an AC scale.
6. Set the meter to an AC scale capable of measuring the respective line voltage (120 volts AC, 208 volts AC, or 240 volts AC) for that model.
7. Insure that the meter clips are isolated to prevent any inadvertent electrical shorts.
8. Apply power to the oven, stand back, and initiate a cook cycle.
9. A meter reading equivalent to, or slightly lower than the applied line voltage denotes the proper primary input to the transformer. This would suggest the high-voltage system to be the trouble area. Extremely low, or no voltage reading here would indicate problems in the control section.

12.3 POWER OUTPUT CHECK USING A CENTIGRADE THERMOMETER

The maximum amount of output power, in watts, that a microwave oven is capable of producing can be determined by performing one of the following tests. There are several different procedures, all of which give satisfactory results by measuring the temperature rise of a given amount of water over a specific period of time. Depending on the type of oven, the available test equipment, and the individual preference, one or more of the following methods will provide a suitably accurate measurement of the output power (in watts) of any microwave oven.

While this test will provide valuable clues as to the degree and the source of heating problems, it should be noted that variations or errors in the performance of this procedure will produce results that will reflect those variations. It would therefore be advisable to make additional power tests in cases that are marginal. Further, if the line voltage is below normal the magnetron output power will be correspondingly low.

1. Use a CENTIGRADE thermometer and a plastic container with a 1000 cubic centimeter capacity. Pour exactly 1000 ml, (1 liter) of cool tap water into the bowl, stir the water with the thermometer, then measure and record the temperature.
   A. For an accurate measurement the initial water temperature must be between 17°C (62.6°F) and 27°C (80.6°F).
2. Place the bowl in the center of the oven cooking shelf. DO NOT leave the thermometer in the bowl.
   A. To avoid an erroneous measurement, the shelf must be in place and any metal racks must be removed.

3. Using the second hand of a watch and *not the oven timer* (an inaccurate timer may be the source of the problem that necessitated the wattage check), heat the water for exactly 62 seconds. It takes about two seconds for the magnetron tube to reach full oscillation in most models.
   NOTE: When testing ovens with dual magnetrons, a true and more accurate measurement may be obtained by using two test bowls, each containing 1000 ml. of water, and heating them simultaneously. Additionally, using just one bowl, each magnetron's output can be measured independently by **first observing appropriate precautions,** then disconnecting a primary lead from one of the two HV transformers, thus disabling that one side. Then, with one side non-operational, test the output of the other side.
4. When the time expires remove the bowl immediately, stirring the water with the thermometer while doing so. Re-measure and record the temperature of the heated water.
5. Subtract the starting water temperature (step 1) from the ending water temperature (step 4) to obtain the temperature rise. If using two bowls, determine the temperature rise for each bowl then add the two amounts together to get the total temperature rise.
6. Multiply the total temperature rise by a power factor of 70 to get the output power in watts. For example:

Using one bowl:	*Using two bowls:*
Starting water temperature = 22°C	Temperature rise of bowl 1 = 4.5°
Ending water temperture = 31°C	Temperature rise of bowl 2 = 5°
Temperature rise = 31 − 22 = 9°	Total temperature rise = 4.5 + 5 = 9.5°
Output power = 9 × 70 = 630 watts	Output power = 9.5 × 70 = 665 watts

A variation of, and perhaps a more precise method than the preceding test, is to use two bowls, each containing 1000 ml (1 liter) of water. And, instead of heating the water for 62 seconds, the water is heated for exactly 2 minutes. Before heating the water, though, an average starting water temperture is calculated in the following manner:

Starting water Temperature of bowl 1 = *T1*
Starting water Temperature of bowl 2 = *T2*
Average starting water Temperature = *AT*

$$AT = \frac{T1 + T2}{2}$$

After heating for 2 minutes, remove the bowls, stir their contents with the thermometer and re-measure the water temperatures. By substituting the ending temperature readings for the starting temperature readings, use the same formula to calculate an average ending temperature. Subtract the average starting temperature from the average ending temperature and multiply the remainder by 70 to obtain the output power in watts.

12.3.1 Power Output Check Using a Fahrenheit Thermometer

An alternate test is conducted in the same manner as was the preceding centigrade-thermometer test, except that a FAHRENHEIT thermometer (with a range over 180°F.), a different amount of water, and a different power factor are used. Fill a Pyrex^R or other suitable container to the 16 oz. (2 cups) mark with cool tap water. Measure and record the initial water temperature. Heat the water at full power for

62 seconds, then remove the container while stirring the water with the thermometer. Measure the heated water temperature and subtract the initial temperature reading from that amount. The difference represents the temperature rise. Multiply the temperature rise by a power factor of 18 to obtain the magnetron's output power in watts. (Note: Opinions as to the most accurate power factor to use with this test seem to vary by a digit or two. The factor of 18 used here has proven accurate, and represents an average of other possible factors.)

This test can be adapted to use two containers, each filled with 16 oz. of water, by increasing the cook time to 2 minutes and using the same types of average temperature calculations that were used in the preceding two-container variation. Once the average temperature rise is determined it is then multiplied by the power factor of 18 to obtain the output power in watts.

12.3.2 Increasing or Decreasing the Output

The power output of models with more than one secondary tap on the HV transformer may be increased or decreased by approximately 25 to 40 watts (depending on the model) by changing the secondary tap to "HI" or "LO", respectively.

As a general rule, customers can determine for themselves if the power output of their oven is "in the ballpark" by making the following test: Place 1 measured cup (8 oz.) of cool tap water into the cooking cavity of the oven. If the water begins to boil within 2 ½ to 3 ½ minutes, the oven is performing normally.

12.4 MAGNETRON FAILURE MODES

It is important to be aware of the proper way in which to handle magnetron tubes. Like other electron tubes, the magnetron must be handled with a reasonable amount of care. Handle the tube by the housing only, use caution not to touch or strike the antenna dome, whether it be glass, ceramic, stainless steel, or copper. Touching the dome may leave a residue of skin oil which could cause corrosion, or interfere with the R.F characteristics of the material resulting in premature magnetron failure.

Common magnetron failures are grouped into categories as follows:

1. Shorted: In this category there are several separate causes of failuie. In each type of failure the condition results in a very high secondary current which will usually cause the power transformer to grumble. In *Amana* and other models with high-voltage circuit protection, the protecting device (usually a fuse or thermal fuse) will open. Also, under certain circumstances the line fuse may open.
   - A. Internal plate-cathode short. This type of short can create such an abrupt rise in current flow through the HV diode that the diode breaks down and shorts. Repeated diode failures are a good indication of a magnetron that is intermittently arcing internally (cathode to plate), or breaking down into a plate-cathode short after a period of operation.
     - (1) Arcing internally. This condition will normally be accompanied by a ticking or crackling sound.
   - B. When the vacuum envelope of the tube is ruptured, air enters the tube and causes internal arcing which, in some cases, is visible through small vent openings in the waveguide end. In tubes with glass domes the antenna will glow with a violet or bluish cast when high voltage is applied.

C. In the case of the older glass dome tubes, upon examination, the antenna within the dome will no longer be shiny, but rather have a dullish appearance from oxidation. Notice, in Figure 12-3, the difference between the intact magnetron dome on the left and the ruptured dome on the right.

D. The RF capacitors or their leads may short or arc-over to the chassis.

2. An open heater or filament. This type of failure can be detected by performing the magnetron test outlined in *Section 12.5.* As the filament ages with use it becomes more fragile, eventually breaking down and opening. In many models there are small vent holes in the waveguide that make it possible to observe the magnetron dome during operation. A healthy glow indicates that the magnetron filaments, as well as the filament transformer, are operating normally.

   A. Symptoms: A magnetron with open filaments will produce no heating power. In addition, a sizable spark when the capacitor is discharged indicates an open filament, an open filament transformer secondary, or an open connection between them.

3. Loose filament connectors. If the connectors that slip onto the magnetron terminals become loose or are improperly crimped, the following sequence of effects will occur:

   A. Initially, the resistive or loose connection will cause a reduction in the power output of the magnetron due to a diminished filament input. Eventually, due to the relatively low voltage potential and high current flow, resistive heat builds up. As this occurs the connection further deteriorates and the magnetron intermittently fails to conduct at all. This symptom has the appearance of a defective magnetron, and indeed has been frequently mis-diagnosed as such. Therefore, while you may suspect the magnetron, do not replace it until the integrity of the terminal connections are verified.

   B. Symptoms: An unusually fearsome spark is produced when discharging the capacitor. Also, evidence of resistive heating between

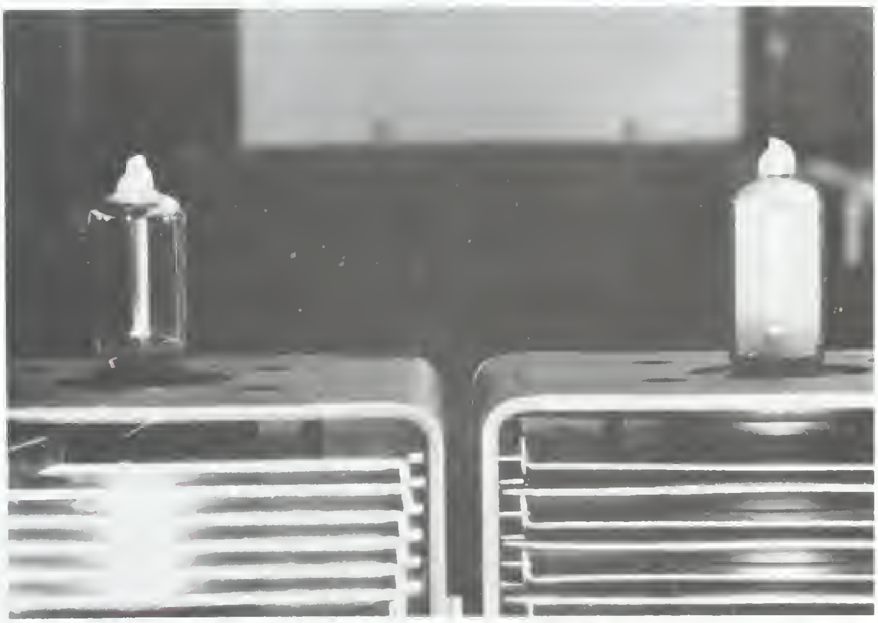


Figure 12-3 Intact dome (left), ruptured dome (right).

the filament terminals and connectors. This ranges from a slight discoloration of the connector, the terminal, or surrounding insulator to the more obvious charred, melted, and decayed appearance as pictured in Figure 12-4.

4. A filament breakdown can also occur *after* a few minutes of normal operation. An initial check with an ohmmeter shows the filaments to be intact and no short to chassis ground. However, not long after the magnetron reaches what appears to be normal oscillation, the normal hum of the high-voltage transformer suddenly degrades into a distressed moan. It sounds as if the transformer is failing, but it is merely feeling and protesting the effects of the extreme current flow caused by the filament breakdown of the magnetron tube. Replace the magnetron tube and re-test the unit.
5. Low or weak output gradually becomes a problem as the emission characteristics of the cathode begin to wear out. The symptoms are:
   A. The plate current will take longer (more than 2 to 3 seconds) to get to its normal operating level.
   B. Assuming the line voltage is normal, the plate current does not reach a level high enough to produce steady magnetron oscillation.
   C. An output wattage check reveals low power output. If the output power is 30 percent less than normal, or more, replace the magnetron.
6. Moding is when a magnetron oscillates in one or more undesired modes (or frequencies for which the tube was not designed). The symptoms include:
   A. Overheating for no apparent reason and eventually breaking down internally.

Figure 12-4 Indication of a loose filament connector.

   B. A dull or very erratic flickering of a power test light as a result of the low power output—food will require longer cooking times.

7. Off frequency: Under certain circumstances the physical characteristics of a magnetron tube, either from the factory or after some use, may be such that the tube oscillates just *slightly off* of the 2,450 MHz oscillating frequency. In these cases there is no abnormal noise, the power test light will illuminate normally, the power output check will be normal and may even flaunt a *higher* than normal output. However, the resulting symptoms will be uneven, unsatisfactory, and unacceptable cooking results that will vary with different types of food items.
8. RF leakage: A magnetron may be emitting dangerous amounts of energy from around the RF gasket. This may be the result of a poor union when first installed, a loose magnetron, or a burned RF gasket. This condition sometimes causes a faint crackling sound during operation.

   Although it's rare, magnetrons will fail structurally so that leakage radiates from the magnetron housing. Eventually the stray RF energy, unable to escape the component compartment due to the metal cover, can cause intermittent and baffling problems with the control panel circuitry. These symptoms are perplexing because the problems disappear when the cover is removed. If the leakage levels around the structure of the magnetron exceed 1mw/cm^2, corrective action should be taken. This may include replacing the magnetron tube.
9. Insulation breakdown can occur to the internal leads of the magnetron. This condition may occur over time due to degradation of the material. This is rare, but appears to result from high temperatures for an extended period of time. Also, if the leads are touching the metal filter box, they may give way to arcing (arc-over) through their insulation to the metal chassis.
10. Glass dome tubes: While most magnetrons in use are not of the glass dome type, a few still exist. Other than those mentioned previously, failure modes that are typical of these older tubes and require their replacement, are as follows:
    A. A hairline crack in the glass dome may be the result of poor handling or striking the glass. Thermal or mechanical stress can also cause this condition which is referred to by some as a "*tipoff crack*".
    B. Reflected energy from no-load operation, the improper use of metal, or a non-rotating stirrer blade will create an abnormally high amount of power on the antenna's glass dome. This causes the glass to soften in that area. Soon the atmospheric pressure outside the dome pushes the softened glass inward toward the vacuum that exists inside the dome. The glass continues to "*suck in*" until a hole forms, destroying the vacuum envelope.
11. *Physical damage* caused by mishandling. A cracked magnet will cause an intermittent arcing condition.
12. *Unexplained arcing*. There is a strange phenomenon that sometimes occurs with certain magnetrons. When line voltage becomes unusually high, unexplained arcing occurs in the high-voltage section. The curious arcing usually manifests itself across the capacitor terminals or from a capacitor terminal to chassis ground. This bizarre occurrence may damage the magnetron, so replacement may be necessary. Also, inspect all high-voltage connections and insulators for carbon traces and insure the connections are tight.

12.5 MAGNETRON TESTING

In most cases the RF capacitors are part of the magnetron assembly and cannot be replaced or removed, therefore the following test will consider the RF capacitors as part of the magnetron assembly. Before making these tests the RF capacitors should be discharged by placing a screwdriver blade against the metal magnetron housing and to each capacitor terminal. While the following resistance checks will conclusively reveal a magnetron that is shorted to chassis ground or one that has open filaments, they will not detect a magnetron that is failing under the stress of circuit operation.

1. Unplug the oven.
2. DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S) AND THE RF (by-pass) CAPACITORS.
3. Carefully remove all the leads from the magnetron terminals.
   A. In some models the magnetron terminals, or the leads to them, are rigid and can be damaged by excessive movement. So it may be necessary to support the terminals while gently jiggling the leads loose. It is important that the leads be reconnected to the same terminals they were removed from (assuming the unit was wired properly), so note their positions accordingly.
4. Set the ohmmeter to its lowest resistance scale. As shown in Figure 12-5,

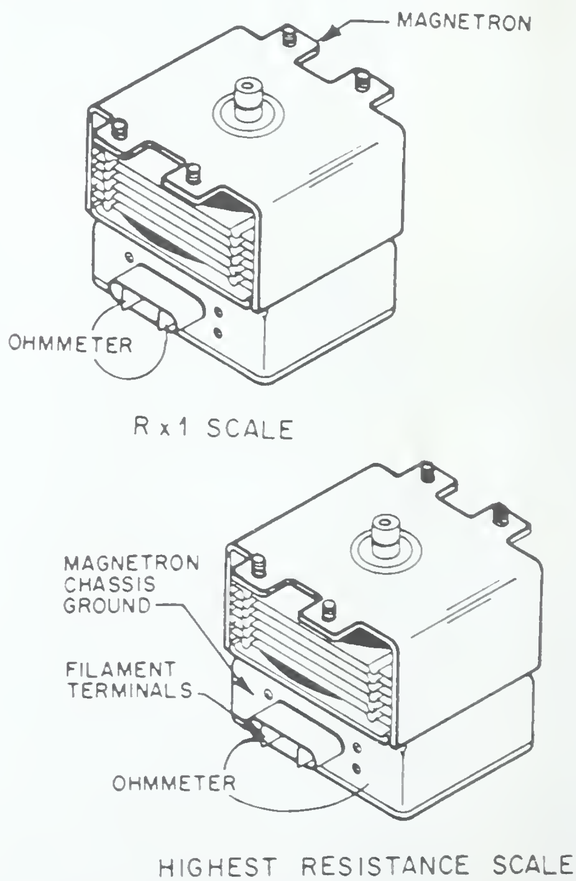


Figure 12-5 Measure the resistance across the magnetron terminals and to chassis ground. (Illustration taken from service literature copyrighted 1983 by Litton Microwave Cooking Products. Used by permission.)

measure the resistance from one magnetron terminal to the other in either direction (meter lead polarity is not a factor). The magnetron filament resistance should be less than 1 ohm.

5. With the meter set to the R X 10,000 scale or higher, check from the magnetron terminals to the metal magnetron housing. The meter should read infinity regardless of the meter lead polarity. Even a slight reading would indicate a defective magnetron tube.

12.5.1 Magnetron Plate Current (Ip) Test

To measure and analyze the operating current of the magnetron tube, the following procedure may carefully be used. Assuming the proper line voltage is available at the primary of the power transformer, this test will verify and help isolate a problem in the high-voltage section of the oven. The normal plate current reading will vary with different high-voltage systems, even within the same model line. In systems that use identical components, the two main factors that contribute to this variance are; varying capacitor tolerances, and the setting of the high-voltage tap on the transformer secondary (if more than one tap is provided). The additional tap is there to compensate for capacitors that are at either extreme of their tolerance. Changing either the tap setting or the capacitor will affect the plate current reading. It is very important to read this *entire* procedure *before* attempting this test.

WARNING: THIS TEST IS CONDUCTED WITH THE OVEN ENERGIZED. VERY DANGEROUS HIGH VOLTAGES WILL BE PRESENT. FOLLOW THE INSTRUCTIONS CAREFULLY AND USE EXTREME CAUTION!
NOTE: THE OVEN MUST BE PROPERLY GROUNDED BEFORE PERFORMING THIS TEST.

1. Unplug the oven, remove the cover and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S) AND THE RF (by-pass) CAPACITORS.

2. Many models (mostly commercial) are equipped with a 10 ohm 10 watt *test* or *monitor resistor* as shown in a popular *Litton* model in Figure 12-6 (*Sharp* uses a 5 or 6 ohm resistor). If there is no test resistor, one must be inserted between the cathode side of the diode and chassis ground in order to perform this test. As shown in Figure 12-7, the cathode lead of the diode is removed from its ground connection, and to it one lead of the test resistor is attached. The other lead of the resistor is connected to chassis ground, so the test resistor is in series with the diode.

3. Make a resistance check of the test resistor to ensure it is not open. If it were open the high voltage would be across your poor meter.

4. Set the meter to a DC scale of 0–10 volts.

5. Refer to Figure 12-8. Verify the proper meter polarity by connecting the meter leads with alligator clips as follows: positive lead to the cathode side of the diode and the negative lead to chassis ground.

6. Place a water load into the cooking cavity.

7. Be sure hands, wires, and tools are clear of voltage areas and stand back.

8. Plug the oven in, and activate the cook mode on *high* or 100% power level. If a power level mode of less than 100% is selected the meter voltage reading will fluctuate as the magnetron is cycled on and off.

9. Record the voltage reading, watching for irregular fluctuations.

10. Turn off and unplug the oven.

This test is a simple application of *Ohms Law,* which states that: *the Current (I) = the Voltage (E) divided by the Resistance (R) or*

$$I = \frac{E}{R}$$

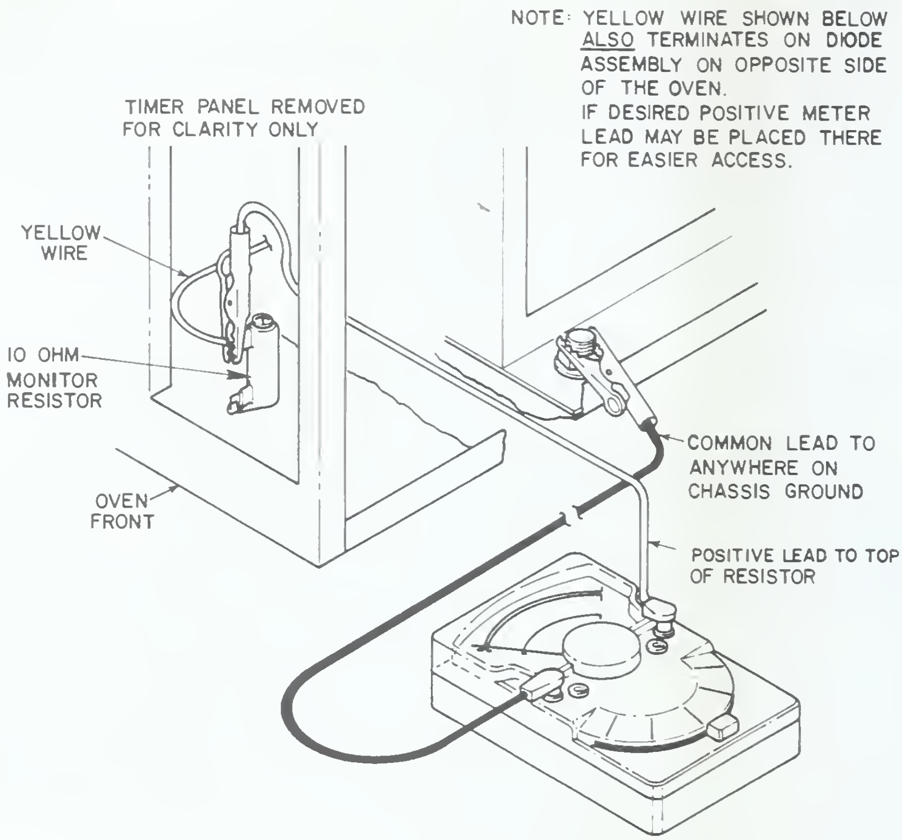


Figure 12-6 Magnetron plate current test set-up. (Illustration taken from service literature copyrighted 1978 by Litton Microwave Cooking Products. Used by permission.)

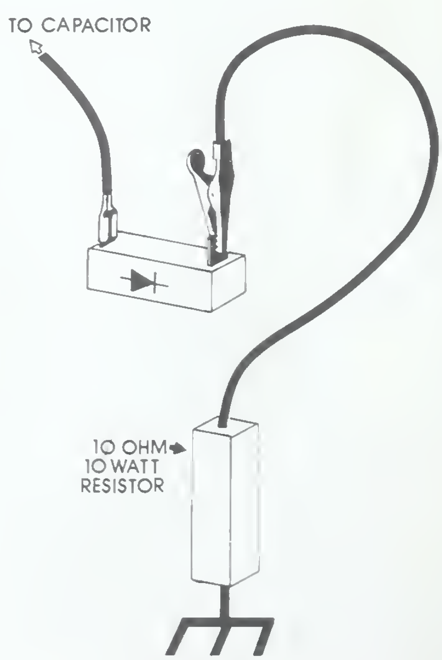


Figure 12-7 Test resistor inserted between the diode and ground.

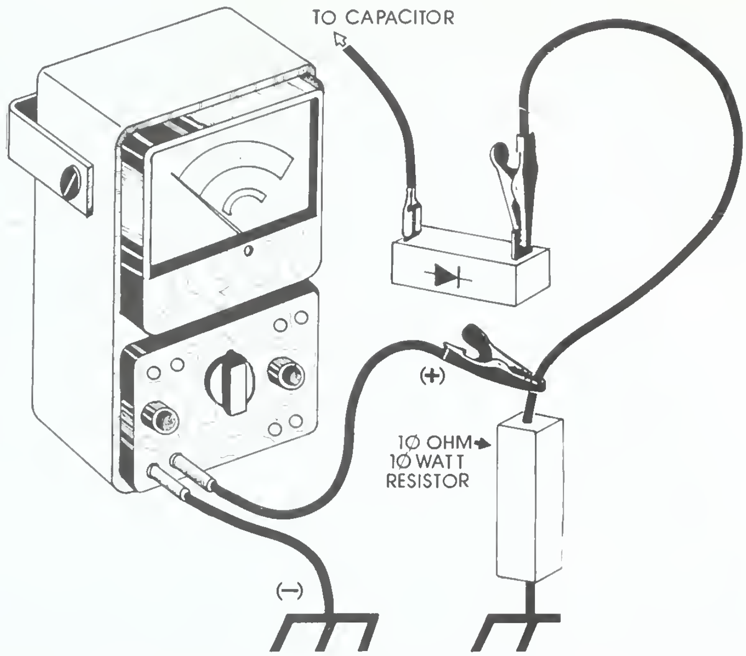


Figure 12-8 Meter connections for the magnetron plate current test. (Courtesy of Michael S. Wagner)

In this case a 10 ohm resistor R, is in series with the magnetron plate. The voltage drop across the resistor as indicated on the meter is E. Since, in a series circuit, the current flow I is the same through any component in the series circuit, the current flow through the test resistor is the same as the plate current. To obtain the answer in milliamps, the quotient is multiplied by 1000 (1 amp equals 1000 milliamps).

Therefore, the formula to determine the magnetron plate current is as follows:

$$\text{PLATE CURRENT IN mA} = \frac{\text{V (meter indicated voltage)}}{\text{10 OHMS (test resistor)}} \times 1000$$

A normal reading will depend on the model, and in many cases, the output wattage capability of the unit. The following chart shows some typical readings.

Rated Output in Watts	*Type of Use*	*Plate Current in DC volts*
400	domestic	2.0 - 2.35
500	domestic	2.4 - 2.9
600	domestic	2.8 - 3.0
700	domestic/commercial	2.9 - 3.5
1000	commercial	3.8 - 5.4
1200	*Litton Jet-Wave*	6.4 - 7.5
1400	commercial	3.0 each tube
2000	commercial	5.4 each tube

12.5.2 Analysis of the Plate Current (Ip) Test Results

A precise plate current *level* is not necessarily the critical factor in determining the proper operation of a magnetron. In other words, a slightly low reading (perhaps 10% below normal) would not in itself indicate a defective magnetron. Instead, watch for signs of fluctuating, or extremely high or low plate current (25% or more above or below normal), as a definite sign of a defective magnetron.

1. If the Ip is normal and there is little or no heat, replace the magnetron.
2. If the Ip fluctuates up and down, often by as much as 50% above or below normal, the magnetron is *moding* and must be replaced.
3. A plate current (Ip) higher than normal, which will usually produce a pained hum from the HV transformer, indicates a gassy magnetron or a short to ground somewhere between the HV diode and the magnetron tube.
   A. Check for wires that are frayed or cut and possibly shorting to ground. Check for a burned area caused by high-voltage arc-over.
   B. Check for a shorted HV capacitor.
   C. Check the filament transformer for the secondary winding shorted to ground.
   D. Check for a shorted diode.
   E. Check for a shorted magnetron. Or, check for a collapsed or deteriorated magnetron dome, which can also produce symptoms similar to a short.
4. A plate current of about ½ of normal indicates that the magnetron is not oscillating. Beside a faulty magnetron, this can be caused by a shorted diode in a *full*-wave voltage doubler circuit, a defective capacitor, or miswiring of the high-voltage section (miswiring can be either the consequence of a previous unqualified repair attempt, or a product of the assembly line on a brand new oven).
5. If the Ip is extremely low, or it takes longer than about 2 to 3 seconds to reach the normal operating level, the tube's emission characteristics have diminished to the point of producing a very low output. The tube must be replaced.
6. If an Ip of zero is read, make an attempt to observe the glow of the magnetron filaments. Many models have one or more small vent holes in the waveguide that make it possible to see the dome of the magnetron. A slight glow verifies the integrity of the magnetron filaments and the presence of filament voltage. If there is no filament glow, or if it is not possible to visually verify these factors, then perform the magnetron and filament transformer tests as outlined in *Section 12.5* and *12.7,* respectively. If, when discharging the capacitor, rather than the usual spark, you behold more of a breath-taking arc, check for either an open magnetron filament, open transformer filament winding, or a faulty connection in the wiring to the magnetron.

12.6 MAGNETRON REMOVAL AND INSTALLATION CONSIDERATIONS

Although magnetron mounting configurations vary to some degree from one model to the next, the following considerations will apply in all cases. Remove any items (such as a watch) that may be susceptible to magnetism. **Make sure the oven is unplugged and the capacitor discharged,** then gain access to the magnetron tube. Before removing the leads, as an additional precaution, the magnetron terminals should be discharged by shorting them to the magnetron chassis with the blade of a screwdriver. Carefully remove the filament leads, taking note of their location. If necessary, remove the thermal protector. Next, remove the magnetron mounting nuts (usually 4). If a standard ⁵⁄₁₆-inch nutdriver does not fit, the appropriate *metric* size must be used. Lower the tube assembly to clear the ceramic dome portion, being

careful not to strike or touch the antenna dome area. Remove the tube from the unit. If replacing the tube, be sure to remove any add-on parts from the original, such as air ducts or baffles, that must be installed on the replacement magnetron. Check the replacement magnetron to insure that the RF (wire mesh) gasket is intact and properly in place in the circular groove around the base of the magnetron dome.

Before installing a magnetron tube it is advisable to inspect the circular opening in the waveguide where the magnetron dome is to be inserted. Examine the rim of the opening for irregularities such as dents, pits, or burns. Any such defects should be sanded (do not use steel wool) until all carbon deposits are removed and the rim is smooth to the touch.

There is another important magnetron-related factor which must be considered when replacing the entire oven cavity (which includes the waveguide). The rim of the circular opening in the waveguide is sometimes painted over. If the paint is not sanded off so that bare metal is exposed, the RF gasket will not make a positive grounded connection against the waveguide flange, and serious RF leakage will result. If this occurs and, because the required post-repair RF leakage check is neglected, the condition is not detected, a serious RF leakage hazard will be concealed when the outer case reinstalled. Much of the stray energy bouncing around within the component compartment will find its way to the air and cooling vent, thus making its escape. The remainder of the emissions will cause erratic operation, and even failure, of sensitive solid state components.

To install the magnetron, insert the antenna portion of the tube assembly into the waveguide, being careful not to strike the dome against the rim of the waveguide opening. While holding the tube assembly firmly against the waveguide, hand tighten the retaining nuts. Then tighten the nuts evenly to insure a proper RF seal. When re-connecting the magnetron leads, insure that the proper phasing is maintained by returning the filament leads to the same magnetron terminals from which they were removed (assuming the wiring was correct initially). Improper phasing can cause intermittent "popping" in the high-voltage system, inconsistent operation, and premature high-voltage component failure.

If there is evidence of a poor connection (discoloration or pitting), the deficient connector should be replaced. If the magnetron insulator is discolored or burned around the terminal, the magnetron should be replaced. It is important that the filament lead slip-on connectors be tightly secured on the magnetron terminals. A loose terminal connector will lead to further tube or terminal failure.

After installing a magnetron tube, an RF emission check with an approved microwave leakage tester *must* be performed in the area of the repair as illustrated in Figure 12-9 and outlined in Section 15.7.

12.7 FILAMENT TRANSFORMER TESTING

In many models the output of the filament transformer can be verified by observing the glow of the magnetron filaments through small vent holes in the waveguide. The filament transformer may be checked for an *open* primary or secondary winding, and in some cases, a *short* to ground, in the following procedure:

1. Unplug the oven and DISCHARGE THE HIGH-VOLTAGE AND RF BY-PASS CAPACITORS.
2. Isolate the filament transformer by carefully removing all connections.
3. With the ohmmeter set on its lowest scale, measure across the terminals of the secondary winding (the polarity of the meter leads is not a factor). A reading of less than 1 ohm is normal for most filament transformers.

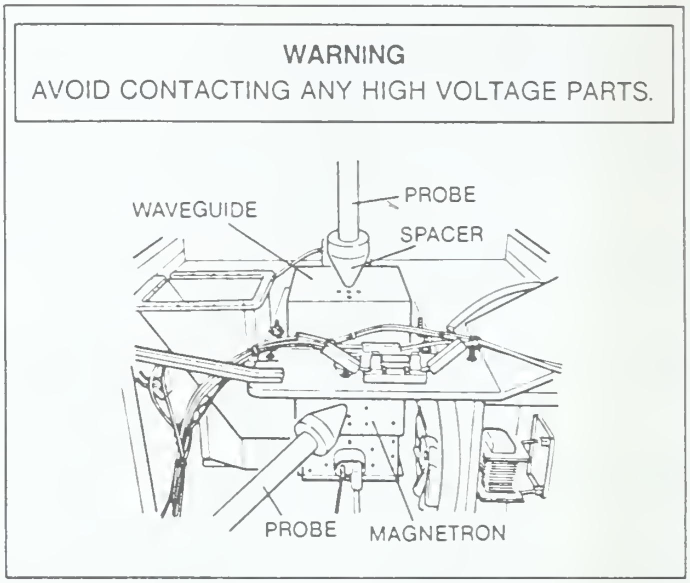


Figure 12-9 Always perform a post-repair RF leakage check. (Used by the permission and courtesy of Matsushita Electric Corporation of America — source material copyrighted 1983.)

A. A significantly higher reading may indicate a poor terminal connection such as a faulty solder or crimp joint where the coil wire terminates into the output terminal.
   (1) A possible corrective action here is to carefully clean the joint by scraping away the thin coating of insulation from a portion of the coil wire near the terminal. If the joint was soldered initially, it will be necessary to clean the surfaces to be soldered of any remaining rosin, flux, or other contaminants, to ensure a good and consistent solder flow. Since it is generally impossible to re-crimp a joint, poor crimp joints should also be soldered, using the same procedure just described.

B. An infinite reading (or virtually no movement of the meter needle) indicates an *open* secondary winding. The transformer must be replaced.

4. Set the meter to its highest resistance scale and measure from either of the secondary terminals to a bare metal area of the transformer frame. There should be infinite resistance (or no reading whatsoever) from the secondary winding to the transformer chassis ground.
   A. When using an ohmmeter on its higher resistance scales, care must be taken not to touch the probes or the areas they are contacting. This is because the resistance of your body will be read by the meter causing an erroneous and misleading indication.
   B. Even a slight reading here indicates a high-resistance short to ground. Close examination may reveal a visual indication of this breakdown in the form of a carbon track or a burned area. Usually the transformer must be replaced; however, a temporary repair may sometimes be accomplished by cleaning out the carbon track and packing the area with high-voltage putty.
5. The primary winding of the filament transformer is resistance-tested by repeating the steps for testing the secondary winding. The only exception is a somewhat higher resistance reading across the primary winding due to

a higher number of turns. A reading from about 5 to 40 ohms, depending on the make and model, is considered normal for the primary winding.

12.7.1 Filament Transformer Voltage Test

In the preceding tests the filament transformer was checked for, among other things, an open winding. However, since the ohmic values of the windings are so low, these tests will not always detect a shorted turn or winding. If a single turn or winding of the transformer is shorted it can reduce the filament voltage output to the magnetron tube by as much as one-half. This condition will not be detected by the plate current test because it does not produce abnormal milliampere readings. Neither is it discovered by an output wattage performance test, which will indicate an acceptable water temperature rise. The following voltage test will measure the output of the filament transformer, thereby either revealing the deficiency or verifying the proper filament voltage. This test, in particular, should be conducted in cases of multiple or premature magnetron tube failures.

CAUTION: THIS TEST IS CONDUCTED WITH THE OVEN ENERGIZED AND WITH HIGH VOLTAGES PRESENT. OBSERVE EXTREME CAUTION AT ALL TIMES.

Read the following directions *thoroughly* before beginning this test. Follow the directions exactly as written while conducting the test.

1. Unplug the oven and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. Discharge the RF (by-pass) capacitors by placing the blade of an insulated-handle screwdriver against the magnetron housing and touching it to each magnetron terminal.

3. Before performing this test, it is EXTREMELY IMPORTANT that the *high-voltage lead* be *positively* identified and completely removed, as described in step 4 of *Section 12.2.1.* **IF THE HIGH-VOLTAGE LEAD CANNOT BE POSITIVELY IDENTIFIED, IT WOULD BE IN THE BEST INTERESTS OF YOUR METER TO OMIT THIS TEST.**

CAUTION: HIGH VOLTAGE *WILL* BE PRESENT AT THE POWER TRANSFORMER SECONDARY (HV) TAP FROM WHICH THE HIGH-VOLTAGE LEAD WAS JUST REMOVED.

4. Leave the filament leads connected to the magnetron. Using alligator-clip type leads, attach one lead to each magnetron terminal. Insure that the alligator clips are not touching. A quick resistance check at this point verifies a good meter connection.

5. Visually inspect the area around the high-voltage tap of the transformer to be sure it is clear of wiring, tools, and any forms of life.

6. Set the meter to a 0–10 volt range on the AC scale.

7. Place a water load in the oven cavity and plug in the unit.

8. Put the oven into the cook mode and, while standing back, note the reading on the meter.

9. Turn off and unplug the oven.

Carefully following the preceding instructions will keep you and the voltmeter from being exposed to high voltages.

12.7.2 Filament Voltage Test Results

Due to the vast number of different makes and models it would be impractical to list all the specific filament voltages here. If you require filament voltage data for a specific model the respective service manual should be consulted. However, it would be safe to assume that a normal filament voltage reading for most domestic models would be in the 2.5 to 3.5 volt AC range. A reading of less than 2 volts AC would be a good indication of a shorted winding, in which case the transformer should be replaced.

Commercial models that use a single high-output tube generally have a higher filament voltage. On the other hand, models that use two magnetrons (to achieve the same high-wattage output) use a filament voltage for each tube which is usually in the range of most domestic models. Depending on the make and model, a filament voltage in the range of about 3.5 to 5 volts AC is normal for most commercial units. As with the domestic models, an extremely low reading would suggest a defective transformer.

NOTE: A transformer failure will normally cause burned (carbonized) areas to be visible or arcing when energized. An odor of electrical burning will usually accompany these types of failures.

12.8 HIGH-VOLTAGE (ALSO POWER OR PLATE) TRANSFORMER TEST

One side of the high-voltage secondary winding is connected directly to the transformer housing and is therefore at ground potential. As shown in Figure 12-10, the other side of the secondary winding terminates in one, two, or sometimes three terminals (or taps). These additional taps, labels "HI", "MID", and "LO" (or "near" and "far" referring to their physical positioning), provide a method of increasing or decreasing the amount of power produced by the magnetron. Normally a continuity check will be sufficient to determine the condition of the high-voltage secondary winding.

Figure 12-10 High-voltage taps.

1. Unplug the oven, remove the cover, and **DISCHARGE THE HIGH-VOLTAGE AND RF CAPACITORS.**
2. Disconnect the high-voltage lead from the power transformer's secondary terminal or tap.
3. With an ohmmeter set to the lowest resistance scale, R X 1, measure the resistance between each of the high-voltage taps (if there are more than one) and chassis ground. The meter should read about 55 to 65 ohms between the terminal marked "LO" and the oven chassis ground. Measuring between the "HI" terminal and ground should show a reading of about 60 to 70 ohms. Notice, due to the increased number of turns in the secondary winding labeled "HI", the resistance is slightly higher. The "MID" tap has fewer turns and the "LO" tap still fewer, so their resistance is correspondingly lower.
   - A. A reading substantially lower than those mentioned would indicate a probable shorted turn or winding. Depending on the extent of the short, the symptoms vary:
     - (1) With deficient high voltage the magnetron will not oscillate properly, resulting in little or no microwave energy being produced. If the magnetron sounds unusual—sputtering, wavering, not achieving full oscillation—and the transformer secondary coil is abnormally hot, suspect the transformer.
     - (2) If the transformer is producing a violent hum and is very hot, the secondary has a major short. This is usually associated with an acrid hot burning odor which is produced by the overheated windings. If the system uses a transformer-protect fuse or high-voltage fuse, this condition will cause the fuse to open. Prolonged operation under these circumstances will eventually open the line fuse.
   - B. If an extremely high resistance reading, or infinity is shown, then replace the transformer.
4. Disconnect the connections to the primary of the transformer and measure across the primary terminals for a normal reading of less than 1 ohm (.22 ohms).
   - A. A substantially higher reading or infinity indicates an open primary.
5. Check from each primary terminal to chassis ground for a normal reading of infinity.
6. Power transformers that incorporate a filament winding may be checked in the same manner as that described earlier for the independent filament transformer.
7. Loose transformer laminations will not be detected with an ohmmeter. However, this condition will cause the unit to emit a loud buzzing sound or vibration in all operational modes.
   - A. This problem can be verified to a degree by disconnecting the transformer primary leads (after unplugging the oven and discharging high-voltage capacitors) and re-testing the unit for the same symptom. If the buzzing and vibrating are eliminated by disconnecting the transformer, and all other tests are normal, suspect loose laminations.

12.9 HIGH-VOLTAGE CAPACITOR TEST

While the following test will detect a defective capacitor, it will not identify one that is marginal and perhaps breaking down under load. These capacitors can short

internally when subjected to the high voltage and current of circuit operation, and yet when checked with an ohmmeter, appear to be normal. So, being reasonably convinced that the other high-voltage components are not at fault, replacing the relatively inexpensive capacitor is sometimes the most certain method.

It may be noted that a replacement capacitor is stamped with the wording "NO PCBs", or something similar. This stands for *polychlorinated biphenyl,* a dielectric fluid that was used in capacitors and other electrical equipment. It has since been determined by the Environmental Protection Agency (EPA) that this type of oil is subject to create a toxic substance if the capacitor should short internally. Therefore the newer non-PCB capacitors are marked accordingly.

To test the capacitor:

1. Unplug the oven.
2. **DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S) AND BY-PASS (RF) CAPACITORS.**
3. Isolate the capacitor from the circuit by disconnecting the leads from its terminals.
   A. If there is an external *bleeder resistor,* it may remain connected but the reading will be the value of the resistor rather than infinity. Capacitors with internal bleeder resistors, such as the one in Figure 12-11, will produce similar results.
   B. If there is an internal diode, as pictured in Figure 12-11, the reading from one terminal (the one to which the diode is internally connected) to the metal capacitor housing will reflect the presence of the diode. Assuming the diode is not shorted or open, a reading in one direction will show the front to back resistance (about 50,000 ohms) of the diode. Reversing the leads should result in a reading of infinity. Anything less than infinity (even a slight reading on the meter) indicates a short in either the capacitor or its internal diode. In either case the capacitor must be replaced.
4. Set the ohmmeter to a resistance scale of R X 10,000 or higher. As shown in Figure 12-12, measure across the capacitor terminals; first in one direction, then reverse the leads and measure in the other direction.
   A. In the case of a DUAL CAPACITOR check from the center terminal (unless the *common* terminal is otherwise marked) to each outer terminal in the same manner as in step 4.

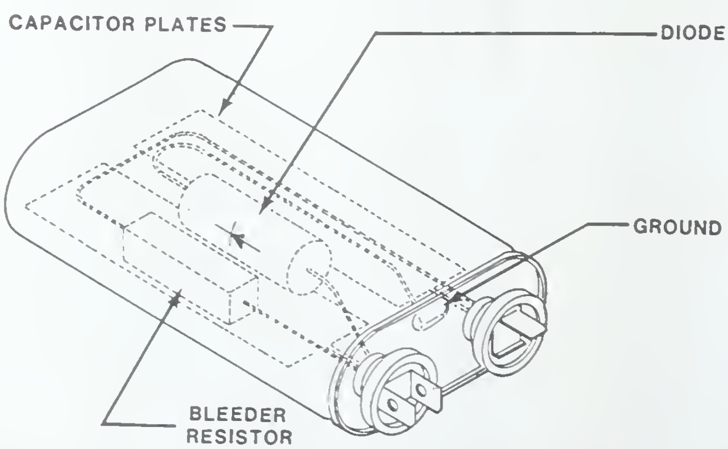


Figure 12-11 High-voltage capacitor with internal diode and bleeder resistor. (Reprinted with the permission of White Consolidated Industries, Inc.)

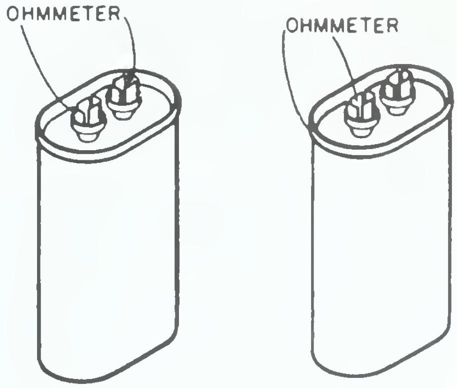


Figure 12-12 Measure the resistance across the capacitor terminals. (Illustration taken from service literature copyrighted 1983 by Litton Microwave Cooking Products. Used by permission.)

5. The meter needle should swing toward the zero mark, peak at about mid-scale, then slowly drift back, either to infinity, or if there is a bleeder resistor, to the value of that resistor. Reversing the leads should produce the same results.
   A. If the meter shows constant continuity the capacitor is shorted and must be replaced.
      (1) When the high-voltage system is energized, a shorted capacitor may either produce a loud "snap", or cause the fuse to immediately open, or both. In either case the capacitor must be replaced.
   B. If the meter shows constant infinity, or just the value of the bleeder resistor, with no momentary deflection, the capacitor is open.
      (1) An open capacitor will be evidenced by the absence of output power from the magnetron.
6. With the meter remaining on the highest resistance scale, measure from each terminal to the metal capacitor case. Each measurement should produce a reading of infinity, with no momentary meter deflection as in the first check. There are two exceptions—see part B of step 1, and part B of this (6) step.
   A. Even a slight reading indicates a leaky capacitor which should be replaced.
      (1) This drop in the capacitor's leakage resistance will usually produce a "popping" sound when the high voltage is applied. Occasionally this condition will weaken or cause the HV diode to short, and often it causes the line or high-voltage fuse to open.
      (2) Another indication of this type of defect is the presence of oil around the terminals or on the exterior of the capacitor. A film of oil is evidence that the oil dielectric is seeping out. This condition may create the same symptoms as a leaky capacitor, or may be the cause of intermittent fluctuations in the magnetron's output power.
      (3) Capacitors may also arc internally, a condition that at times can be heard if the blower motor is disconnected. This type of breakdown may cause the HV diode to fail, the high-voltage or transformer-protect fuse to open (if applicable), the line fuse to open, or all of these symptoms. A rare, but frustrating consequence of this internal arcing, is the blanking out or locking up of the electronic control module when the arc occurs (primarily in *Amana* models). Initially the module can be reset; however,

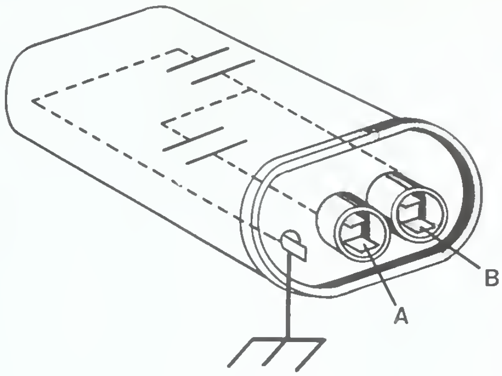
the arcing may eventually damage the module or other components. In time this internal arcing can manifest itself visually by causing the terminal endcap of the capacitor to become bulged or deformed as is the one in Figure 12-13. Eventually deterioration of the dielectric will bring the condition to the point of an internal short.

B. An EXCEPTION to step 6 is the type of dual-rated capacitors that are used mainly in certain revisions of *Litton's* 70 series commercial microwave ovens. As shown in Figure 12-14, one plate of the dual capacitor arrangement is connected to the capacitor case itself. Therefore, measure the resistance from terminal "A" to terminal "B" as in step 4, then reverse the leads and check again. Next, measure the resistance from each terminal to the capacitor case in the same manner. Each measurement should produce a meter deflection that peaks at about midscale and then returns to infinity.
NOTE: When rewiring this type of capacitor, the wires must be reconnected to the same terminals from which they were removed, otherwise improper operation and possibly damage will result.

12.9.1 Frequency Conversion

A special dual-rated capacitor facilitates the conversion of the power supply operating frequency in certain models. (Note: In some models a special transformer is employed for this purpose.) This feature allows models so equipped to be operated at 50 Hz or 60 Hz, depending on the line voltage frequency of the country in which the unit is to be used. Figure 12-15 illustrates a typical procedure for performing a frequency conversion. The accompanying adapted precautionary instructions are as follows: 1) Disconnect the plug from the wall and **DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S) AND BY-PASS (RF) CAPACITORS.** 2) To avoid an electric shock, do not touch any capacitors on the electronic control board. 3) Touch yourself to ground to discharge any static charge that may have built up in your body. 4) If customers operate this oven without having the appropriate

Figure 12-13 The effects of dielectric breakdown.



Dual Capacitor

Figure 12-14 Dual-rated capacitor with one plate connected to ground. (Courtesy of Michael S. Wagner)

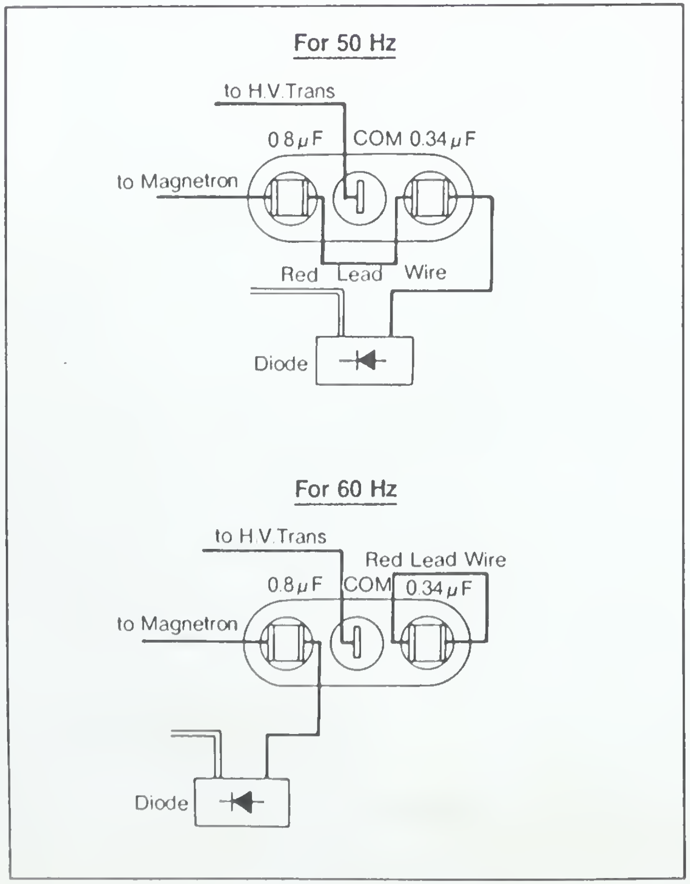
changes made, the high-voltage transformer and/or magnetron may be damaged. 5) Change the high-voltage capacitor wiring as indicated in Figure 12-15A. 6) Adjust the *frequency adjusting switch* located on the DPC board (digital programmer circuit) as shown in Figure 12-15B. 7) Use the attached labels to change the frequency specification accordingly. The specified operating frequency is indicated on two identification plates; one located on the rear panel, and the other located on the front of the oven. A user warning label affixed to the rear panel of the oven must also be changed to specify the appropriate frequency. It is essential that the microwave oven be used only on the frequency indicated.

12.10 DIODE (RECTIFIER) CHECK

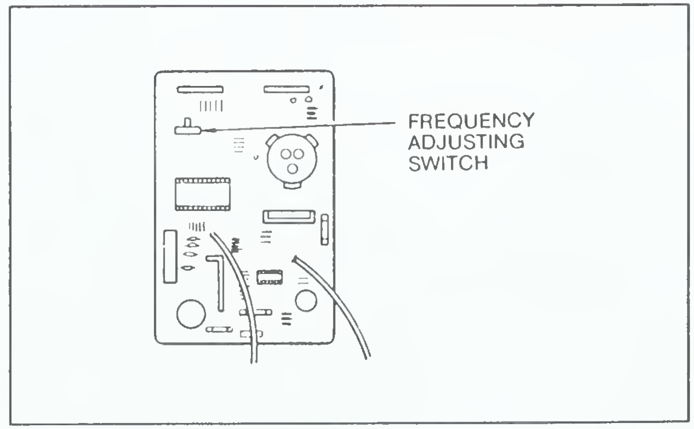
This test requires a meter with a 6 volt, 9 volt, or higher voltage battery to accurately measure the front to back resistance of the diode. Meters with insufficient battery power may read infinite resistance in each direction, mistakenly showing a good diode as being open. In addition, some high impedance (VTVM) or solid state (FET) may also show an acceptable diode as defective, indicating high ohms or open in both lead directions. In any case, a comparison check of a diode known to be acceptable will verify the capability of the meter you are using.

1. Unplug the oven and remove the outer case.
2. **DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S) AND BY-PASS (RF) CAPACITORS.**
3. Isolate the diode by disconnecting the lead that goes to the capacitor (the ground lead may remain connected).
4. Set the voltmeter to read OHMS using a scale of R X 10,000 or higher.
5. Measure the resistance across the terminals of the diode by touching the positive meter probe to the anode and the negative probe to the cathode (the cathode is the point of the arrow that points to ground) as shown in Figure 12-16. A normal diode, depending on the make and model, should read about 50,000 to 200,000 ohms.

NOTE: The polarity of the meter probes, in regard to forward and reverse bias readings, may be relative to the type of ohmmeter being used. The respective polarities and corresponding readings shown here were determined using a *Simpson Model 260* and a *Triplett Model 630-PLK.*



A.



	HOW TO ADJUST FREQUENCY
50 Hz	Turn switch knob to right
60 Hz	Turn switch knob to left

B.

Figure 12-15 Typical frequency conversion. (Used by the permission and courtesy of Matsushita Electric Corporation of America — source material copyrighted 1983.)

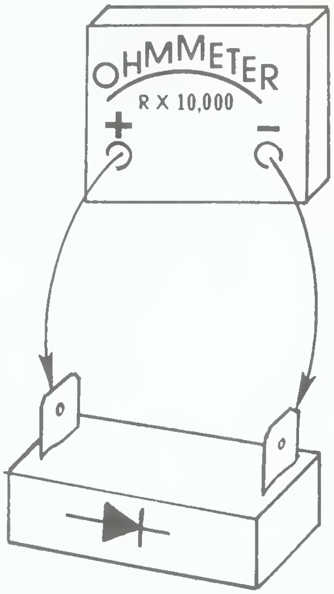


Figure 12-16 Diode check.

6. Reversing the leads (negative probe to the anode and positive probe to the cathode) should produce a reading of infinity, unless there is a bleeder resistor across the diode, in which case this reading would show the value of the resistor.
7. If continuity is read in both directions the diode is shorted, or if infinity is read in both directions the diode is open. In either case the diode must be replaced.
   A. Refer to Figure 12-17. Visual indications of a shorted diode include: a blistered spot (Fig. 12-17A), a burned crack (Fig. 12-17B), and occasionally the diode will be split in two. A shorted diode will also

Figure 12-17A Blistered diode.

Figure 12-17B Burned diode.

give off a pungent electrical burning odor and, if high voltage is applied, evoke a deep groan from the transformer.

8. Diodes of the type pictured in Figure 12-18 should additionally be checked from each terminal to chassis ground for a normal reading of infinity, regardless of meter polarity. Inspect the underside of these diodes for burned areas where the insulation has broken down. When this type of diode breaks down in this manner and allows current to "bleed through" to ground, it is usually accompanied by an electrical burning odor.

12.10.1 Diode Installation

It is important when installing a diode to observe the proper polarity; the arrow should point toward ground. (Some diodes have just a dot or a stripe at one end; it is that end that goes toward ground.) When mounting the diode, keep the anode lead and the diode body well away from metal parts where a possible arc-over could occur. In addition, after replacing a diode—especially in the case of multiple diode failures—the following preventative check should be made: Place a water load in the oven and put the unit into a full power cook cycle for about 5 minutes. Then, quickly unplug the oven, DISCHARGE THE CAPACITOR(S), and cautiously feel the diode with one (perhaps moistened) finger. If the diode is too hot to comfortably touch, or so hot that a moistened finger sizzles, the magnetron is probably breaking down resulting in an extreme amount of current flow through the diode. In this case, if the magnetron is not replaced, the diode will likely soon fail again.

12.10.2 Checking Half-Wave Rectifiers

Diodes such as the one pictured in Figure 12-19 are rarely encountered anymore; however, should the need arise, the test procedure is as follows:

1. Unplug the oven and remove the outer case.
2. **DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S) AND BY-PASS (RF) CAPACITORS.**
3. Isolate the diode by disconnecting the leads from all three terminals.
4. Zero the ohmmeter on the R X 10,000 or higher scale.
5. Touch the positive meter lead to the terminal marked "AC", and the negative (common) meter lead to the terminal marked "+". The meter should read approximately 200,000 ohms. Reversing the leads on the same two terminals should produce a reading of infinity.
6. Touch the positive meter lead to the terminal marked "−", and the negative (common) meter lead to the "AC" terminal. The meter should reflect a resistance of

Figure 12-18 Inspect the underside of this type of diode.

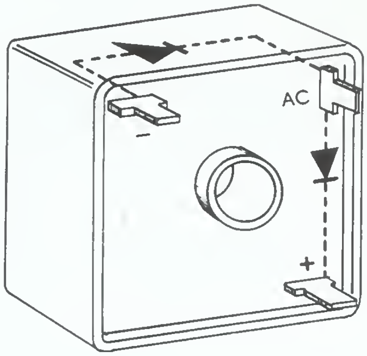


Figure 12-19 Half-wave rectifier. (Courtesy of Michael S. Wagner)

about 200,000 ohms. Reversing the meter leads on the same two terminals should give a reading of infinity.

7. Measure from each terminal to the oven chassis ground. In each case a reading of infinity should be indicated.

12.11 WIRING AND CONNECTOR CONSIDERATIONS

Just as circuit wiring must be accurate, so too must it be routed and positioned properly. The proper dressing of wires is especially important with high-voltage wiring. It is a good practice to avoid routing wires over terminals or sharp edges. Also, wires should not be stretched so tight from one terminal to another that plucking it produces a twang; dress the wire so it is not under tension. During servicing or from normal vibration, cuts, abrasions, or chaffing can occur in the insulation of the wire. The exposed wire may suffer an arc-over, cause a short, a shock, or a burned-open wire and a bear of a problem to find. While these rules appropriately apply to any wiring regardless of the circuit voltage, they are of vital importance when *high-voltage* wiring is involved.

Also, in order to minimize the irksome problem of loose slip-on type connectors, many manufacturers are using a *locking type connector.* This connector, pictured in Figure 12-20, is designed with a locking clip in the center of the receptacle terminal. To remove this type of connector, press down on the extruding lever (locking clip) while gently pulling the connector off of the terminal.

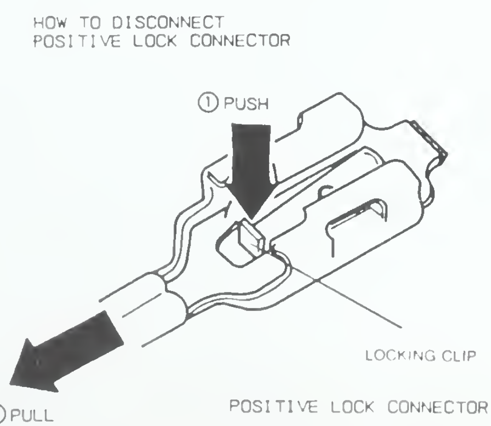


Figure 12-20 Locking connector. (Used by the permission and courtesy of Matsushita Electric Corporation of America — source material copyrighted 1986.)

Control Components; Tests and Failures

chapter 13

13.1 TESTING BASIC ELECTRO-MECHANICAL TIMERS

Rotary dial and digital type electro-mechanical timers consist of an electric motor and one or more sets of contacts, both of which may be checked with an ohmmeter as follows:

1. Make sure the oven is unplugged and the HIGH-VOLTAGE CAPACITOR(S) DISCHARGED.
2. Remove one of the wires from the timer switch terminals and, with the ohmmeter set to the R X 1 scale, measure across the switch contacts. With the timer in the off position the meter should indicate an open circuit (infinity). With the timer turned to a selected time setting the meter should indicate continuity or zero ohms.
   A. Many timers are constructed with internal switch contacts that are not visible. In these cases it is necessary to identify the appropriate terminals. Figure 13–1 illustrates the terminal arrangement and contact functions of three basic types of timers. While the oven schematic or wiring diagram is the only sure way to identify the contact (or switch) terminals, generally, the heavier wires and terminals are those that internally-connect to the contacts.
3. Measure across the timer motor winding. Normal readings of different timers vary considerably. The coil of some timers may give a normal indication of about 1200 ohms, others 2000 ohms, and still others may measure up to 9000 ohms.

● INDICATES CONTACTS MADE	OVEN TIMER TYPE I	OVEN TIMER TYPE 2 & 3
CONTACTS → / ↓ FUNCTION	2 - 3	1 - 2
TIMER OFF		
TIMER ON	●	●

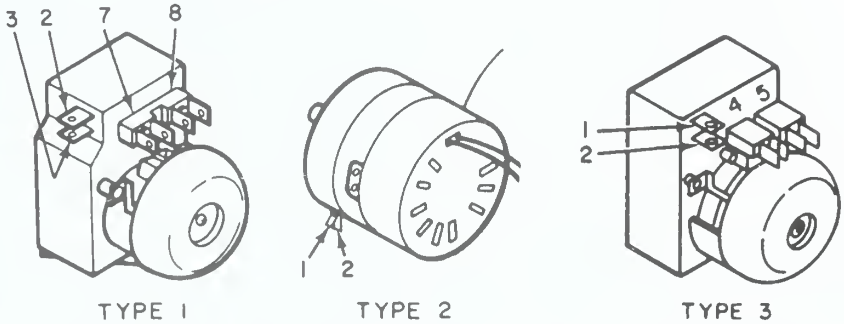


Figure 13–1 Typical timer terminal arrangement. (Illustration taken from service literature copyrighted 1987 by Litton Microwave Cooking Products. Used by permission.)

13.1.1 Operational Timer Motor Check

CAUTION: UNPLUG THE OVEN AND DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S) BEFORE REMOVING OR ATTACHING ANY WIRES. USE EXTREME CAUTION WHEN TESTING AMID "LIVE" CIRCUITS.

An operational check may be performed as follows: With the harness lead reconnected, attach the meter leads to the timer motor terminals with alligator clips. Set the meter to an AC scale capable of reading the appropriate line voltage. Operate the oven. If the proper AC voltage is present at the motor terminals and the timer fails to operate it is either in a mechanical bind or it is defective. An alternative test is to disconnect the harness leads and attach a 115 VAC test cord to the timer motor terminals, then plug in the test cord and observe the timer's operation. If the timer is defective it must be replaced. If, by loosening the timer mounting screws or otherwise repositioning it, the low-torque timer motor begins to operate, it may simply be binding with the faceplate or other obstruction. Adjust the position of the timer accordingly (up, down, in, or out), then re-tighten (do not over tighten) the mounting screws and retest on the longest time setting. (Removing one of the primary leads from the high-voltage transformer [SEE CAUTION ABOVE] will allow for extended timer operations without any output of RF energy.) If the motor stops or hesitates again, the internal gears are worn and the timer must be replaced.

13.1.2 Operational Switch Contact Test

Normally the ohmmeter check will detect a defective set of contacts. However, contacts can intermittently fail during systems operation. This condition can be detected by attaching a voltmeter capable of measuring 120 volts AC (or the respective line voltage) across the switch contacts. Any voltage reading across closed contacts indicates that those contacts are failing.

NOTE: Timers have a variety of designed operating characteristics, such as: a 10 to 20 second delay before rotation is observed, and greater force required to turn the dial at the higher time settings. These and other minor peculiarities may be considered normal unless otherwise indicated by the manufacturer.

13.1.3 Installation Considerations

If possible, center the timer shaft and/or thumbwheel in the faceplate opening. In regard to timers that require the knob to be pushed in to set the time, insure that the timer knob does not bottom out on the surface of the faceplate, impeding the proper engaging and release action. Timers with a thumbwheel should be mounted so the knurled thumbwheel extends sufficiently through the faceplate to allow for proper access, but not extending so far that it may bind with the upper or lower edges of the rectangular faceplate opening that surrounds it. Timers with a pointer or dial on the shaft must be adjusted so that these indicators do not rub against the faceplate or interfere with the shaft opening in the faceplate.

In addition, insure that the harness connectors are tightly and completely secured to their terminals—particularly the timer contact connections. Finally, if the timer has a bell, insure that its ring has not been inadvertently muffled or distorted by wires pressing against it or by improper positioning.

13.2 COMMERCIAL PUSHBUTTON TIMERS

It is intended that most commercial timers be diagnosed and replaced as entire assemblies. Therefore the tests are, for the most part, relatively superficial. And, as a rule, the replacement procedures are fairly obvious. The following test procedures will apply to most pushbutton timers in a general sense, but will not apply in every respect to every timer.

To discourage unauthorized use, many models employ a main on/off switch which is usually hidden. Some *Litton* and *Sharp* models conceal an on/off rocker switch on the underside of the oven, just behind the timer panel. The small on/off toggle switch on many commercial *Amana* models can be accessed by opening the oven door and locating the small rectangular opening just under the front edge of the timer—below the amber and red indicator lights. The toggle arm extends down through this opening. Still other *Amana* models have a disable switch tucked away behind the air inlet grill which is just to the left of the timer. On such models, the grill is removed by slipping a flat-bladed screwdriver under its right-hand side and prying the grill outward until it can be slid to the right and off of its retainer. These switches must be placed in the "on" position for the following operational test.

Usually the nature of the timer malfunction and the type of timer will determine the procedure that will best reveal the problem in the shortest amount of time. An operational test allows the opportunity to observe and scrutinize the workings of the timer. Non-operational checks, such as a series of resistance checks, evaluates each component individually. First though, when the timer trouble is suspected, make a preliminary visual examination of the timer. Check the wiring harness, the plug (loose connections), and the mechanical operation of the timer. Inspect the printed circuit board for deteriorated, fissured, or burned tracks and solder joints. Often the problem will be obvious.

13.2.1 Operational Test

1. Unplug the oven, remove the cover and DISCHARGE THE HIGH-VOLTAGE CAPACITOR.

2. If the unit has a wrapper (outer case) interlock switch it must be put in the service (on) position.
3. Place a sufficient water load inside the cooking cavity, then close the door.

CAUTION: HIGH VOLTAGES ARE PRESENT DURING THE COOK CYCLE. USE EXTREME CAUTION AT ALL TIMES. OBSERVE APPROPRIATE SAFETY MEASURES WHEN CONDUCTING TESTS ON "LIVE" CIRCUITS.

4. Plug in the oven, then open and close the door. If the main on/off switch is in the "on" position, this should bring the oven up to the idle mode. The oven's entering the idle mode and exhibiting all the preliminary functions of that mode, verifies the proper operation of the *holding relay* in models so equipped. (Some models have no idle mode, in other words; when plugged in, they go right in to a ready mode.)
5. Push in button #1 which should put the oven into a cook cycle. The typically red cook light should be glowing.
   A. Some older units require a magnetron warm-up period of anywhere from 3 to 10 seconds before allowing the application of high voltage. In these type of units it is important to verify that delay. And, doing so will also serve as a test of the *warm-up (or delay) relay*.
6. Locate the timer reset solenoid (Fig. 13-2) and observe the action of its plunger as you open the oven door. The oven should stop cooking and the solenoid plunger should retract smartly into the solenoid, releasing the latch assembly so that button #1 pops back out.
   A. A sluggish or weak reset solenoid may be livened up by a few drops of a good quality lightweight lubricant. Sometimes it is necessary to remove, clean, and lubricate the solenoid plunger in order to restore its snappiness. Usually these solenoids do not get out of adjustment, but it does happen. So, experiment with different positions to achieve the best action. It will also help considerably to clean and

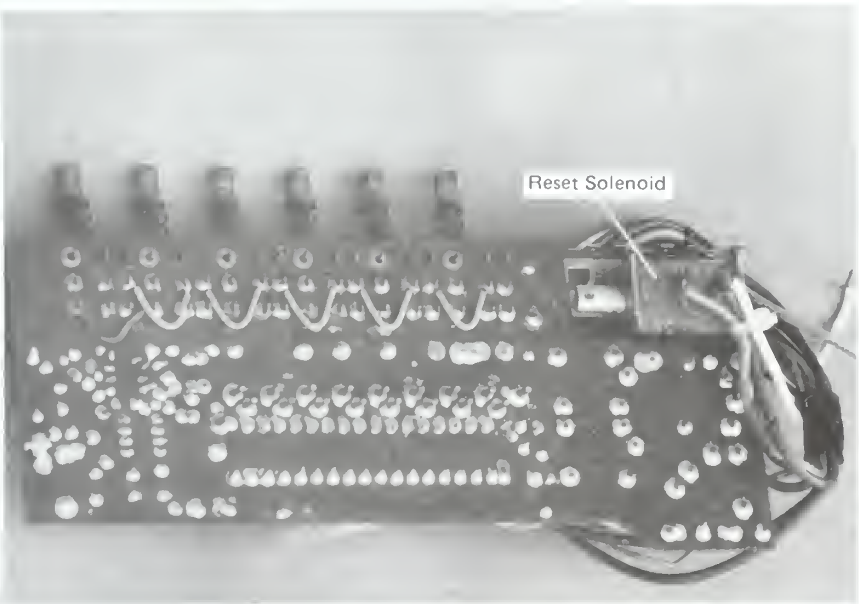


Figure 13-2 Timer reset solenoid.

lubricate the button latch assembly as well as in between and around the buttons themselves (an air compressor comes in handy for this).

B. If the plunger offers little or no attempt to "plunge", the solenoid is probably open and should be replaced (see the resistance checks outlined in *Section 13.2.2*). Often the solenoid casing will be cracked, discolored, or blistered.

   (1) It is felt that this may be caused by the oven door being left open, thus leaving the solenoid energized over a long period of time—an operation it was not designed for—until it finally heats up and opens. Subsequently *Litton* devised an RC (resistive-capacitive) network (Fig. 13-3) that modified their systems so that when the door was opened the solenoid would only receive a pulse, regardless of how long the door was opened. That has saved a lot of solenoids, but, unless the plunger and switch-bank linkage are working smoothly, that pulse is sometimes not enough to reliably reset the timer.

C. On the other hand, if the button releases but will not latch when pushed back in, the plunger is sticking inside the solenoid due to a magnetic build up. Adding more tension to the flat metal spring (if still intact) that collars the plunger, as well as cleaning and lubrication, will help. Also, a proven solution, short of replacing the solenoid assembly, is to remove the plunger from the solenoid coil so that the top of the plunger is accessible. Lightly sand the top of the plunger in preparation for soldering. A drop of soldering flux will help in applying a small film of solder to the top of the plunger. The raised area created by the solder keeps the plunger from seating so completely that any residual magnetism causes it to hang up. But, at the same time, it does seat far enough to allow the execution of its reset function. If extreme buzzing occurs, when the solenoid is energized, it may be necessary to remove the plunger again and lightly file away some of the solder.

D. When the plunger fails to spring back out of the solenoid in *Sharp* timers, a missing or broken spring could be the cause. The tiny spring is (or was) located at the lower end of the switch assembly, attached to the latch bar. The action of the spring helps to set the switch mechanism, and in doing so, also pulls the plunger back into its deactivated position.

E. A meter may be attached to the solenoid terminals to monitor the release voltage, although the proper voltage may be AC or DC and varies considerably with different timers.

7. Next, close the oven door and re-push button #1. The cook light should come back on, the cook relay should be energized, and the oven should be

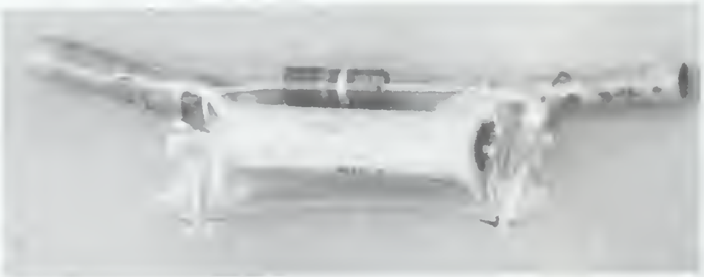


Figure 13-3 Reset solenoid RC network.

in full cook operation. Allow button #1 to compete its time cycle. When it does, listen for the bell or buzzer, and watch for the button to pop out.

A. If the cook relay fails to activate, unplug the oven. DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S), and carefully connect the meter leads across the relay coil terminals. Set the meter to read the appropriate line voltage and put the oven into cook once again. If a low or no reading is indicated (zero volts), the timer may be defective, although other correlative components should be checked before replacing the timer.

8. The accuracy of the timer may be checked by a stop watch or a time piece with a second hand. Close the oven door. Ascertain the preset time for each button. Then, one at a time, select each button and monitor the elapsed time with the sweep hand of the watch.

13.2.2 Commercial Electro-mechanical Pushbutton Timer Resistance Checks

Unplug the oven, DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S), and remove the timer mounting screws. Move the timer far enough away from the oven face to reach in and disconnect the timer plug from the wiring harness. Remove the timer unit from the oven. Zero the ohmmeter on the R X 10 scale and measure the coil resistances of the following components. The normal readings provided here are approximate and vary with different timers. However, results substantially different from these should be reasonable cause to suspect a defective part.

Time motor	600 ohms
Reset solenoid	400–800 ohms
Buzzer coil	850 ohms
Bell coil	850 ohms

In every case the ultimate verification is replacement. Due to the lack of specific information, in many cases this is the only alternative. When it comes to solid state commercial timers, replacement is, regrettably, the *only* choice in most instances.

13.3 SOLID STATE COMMERCIAL TIMERS

When symptoms indicate a possible problem in the timer there are but a few ways in which to test that likelihood. The symptoms themselves can give ample evidence of a defective control board. Whereas all of the following symptoms apply to electronic commercial-type timers, many of the indications are equally symptomatic of most domestic-type electronic control panels.

13.3.1 Symptoms That Can Denote a Defective Electronic Timer

SYMPTOM:

Any type of irregularities or inconsistencies in the display, such as: 1) missing, dimming, flashing, flickering (a slight fluorescent flicker is normal), or overly bright numbers or segments; or 2) the occasional appearance of illogical or mysterious Chinese-like characters (this may also be the result of improper or inadequate grounding).

SYMPTOM:

Any type of programming problems, for example: 1) Pressing one number or function and the panel responding with another; or, some pads program and others do not. These symptoms may be caused by either the touch panel or the control panel or both. When these panels are available separately a determination of fault must be made. *Section 13.5.1* and *Appendix I* will be of great assistance toward making a logical conclusion. 2) Limited or no programming functions. An exception to this symptom is the fact that some models made by *Sharp* will not program unless the *stop switch* is in the closed position. Therefore the oven door must be closed and the stop switch properly adjusted before the control panel will accept programming. 3) The control panel "locks up"; maybe one or more numbers will be displayed, but the panel will not reset or program.

SYMPTOM:

The control panel "kicking out" of a cook cycle prematurely, then possibly "locking up". The oven may have to be unplugged then plugged back in before the panel will accept programming. Possible causes: poor or improper grounding; or, excessive amounts of stray RF leakage, either from the latch side of the door, or from the magnetron within the component compartment. If removing the outer case alleviates the symptom, suspect leakage from the RF gasket or the internal structure of the magnetron.

SYMPTOM:

The control panel counts down too quickly or too slowly. Inaccurate timing may also be the result of an oven (of the type that can be converted from 50 to 60 cycles and vice-versa) being set for the wrong voltage or frequency for the area in which it is being used.

SYMPTOM:

The control panel will not start, or fails to count down when started; or, the panel counts down but neglects to activate the cook relay, triac, stirrer or blower motor, or other panel-controlled component. This may also be the result of a mis-adjusted or defective interlock switch, faulty wiring or related connections, or an open thermal protector or fuse.

> NOTE: The triac or triac module (part of many control units) may be checked in several ways, all of which are outlined in *Sections 13-12* through *13.16*.

SYMPTOM:

Either *all* indicator lights are lit, or no display at all, as though the panel is "dead". (In the case of no display or a "dead" panel, ensure that the low-voltage control transformer is supplying the appropriate voltages. Or if the LV transformer is part of the control board, check for the appropriate input (primary) voltage to the panel before judging it to be defective.)

SYMPTOM:

Either a continuous beep or buzz; or none at all.

SYMPTOM:

The timer buttons remain depressed, thus holding the oven in a continuous cook mode. *Litton* and some other models use individual pushbuttons that are soldered on to the printed circuit board. These buttons may stick in the depressed position due to inadequate clearance through the cutouts in the timer faceplate. In these cases the circuit board position may be adjusted to equally center the buttons in their openings, ensuring that the cutouts and buttons are free of grease and residue. In more extreme cases the size of the hole can be increased by filing the sides of the obstructing cutouts with a small, fine file (the circuit board must be removed first). Then clean any metal filings from the casting and re-assemble the timer, making sure that the timer board is centered so that the buttons operate freely.

Self-Diagnosis: As digital circuitry becomes more sophisticated more manufacturers are providing a self-diagnostic test sequence that can be programmed into the control unit. The control panel responds, in most cases, with a code that indicates the likely problem area. For the respective test and related codes for any of the various models that offer this feature, consult the appropriate service manual or contact the manufacturer.

13.4 DOMESTIC CONTROL CIRCUITS—CHECKS AND FAILURES

If the new technology is reflected anywhere, it is in the control circuitry of the sophisticated microwave ovens designed for home use. It seems, paradoxically, that as technology advances—the field-availability of the corresponding technical data declines. Indeed, the service literature testing procedures for many control units amount to nothing more than programming instructions, although the value of these should not be minimized. Not knowing how to operate the oven you are about to repair can be quite perplexing to the anxious onlooker who owns the unit.

Isolating a fault in a domestic control panel is accomplished, for the most part, by observing symptoms, just as with the preceding commercial units. In fact, all of the symptoms, causes, and corrections just listed for commercial control panels apply equally to their domestic counterparts.

The service literature supplied by many manufacturers provide input and output data for the respective control unit. In these cases, a fairly certain diagnosis can be made using that data. A few non-U.S. manufacturers provide detailed schematic information for their commercial and domestic control panels. In these cases, the servicer has the option of either attempting to repair the unit at the board level, or simply replacing the entire panel. Either way, the *option* is nice.

Many control panels are designed to supply the drive voltage for components such as the blower and stirrer motors, an external triac or relay, the transformer primary winding, and so forth. The panel's output in each case can be verified in the following manner: 1) Unplug the oven, remove the outer cover, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S). 2) Attach a meter (using insulated alligator clips) capable of the measuring the intended voltage to the input terminals of the component in question. (When no technical data is available, the appropriate drive voltage for a given component can usually be ascertained from the case of the component itself). 3) Operate the oven and observe the reading on the meter. 4) If the proper drive voltage for that component is shown, the panel is operating normally in that respect. 5) If an abnormal reading is obtained, either the panel or the wiring in between is at fault.

In conjunction with the preceding symptoms, some additional, rather uniquely domestic-type control panels symptoms are as follows:

SYMPTOM:

Glass touch panel lock up. The panel will not program or reset and possibly a row of numbers are displayed. Before replacing the control panel, *ensure* that the oven is properly grounded and polarized. Static discharge control panels in ovens manufactured by *Amana* and *Tappan* are particularly sensitive in this respect.

SYMPTOM:

Glass touch panel "starts", but immediately stops and either displays the time remaining, or reverts back to displaying the time of day. Once again, suspect a grounding or polarization problem first—especially with a *Tappan-made* model.

SYMPTOM:

The time-of-day clock does not hold or keep the correct time.

SYMPTOM:

Temperature probe, sensor cook or other special features do not function properly. Do not assume the control panel is at fault, though, until the temperature probe, humidity sensor, or other related circuitry and wiring are checked. Also, tactfully determine if the operator is using the feature properly.

SYMPTOM:

The oven cooks constantly, regardless of the power level selected. Check the control panel's triac-drive output as described in *Section 13.12.2.* If a constant voltage is measured when no cook operation has been initiated, or a constant voltage is shown during defrost and other low-power operations, the control panel is defective and must be replaced.

SYMPTOM:

The program erratically shifts or jumps to different functions or memories, or resets itself by erasing the display—except possibly for the colon.

SYMPTOM:

If while counting down, the display jumps or skips time, suspect the panel if the grounding is proper and the polarity correct.

SYMPTOM:

The control module (*Amana*) appears to be "dead". Indeed, it may well be, but first check for an open *thermal fuse* on the magnetron or cavity, or both.

13.5 MYLAR (MEMBRANE) TOUCH PANEL OR THE CONTROL PANEL—WHICH?

For those who like games of chance, the process of determining whether programming problems are being caused by the control panel or the touch panel can be quite challenging—to your skill as well as your patience. Making the right choice becomes

especially venturesome if the symptoms are intermittent; basically it becomes an educated guess with a 50–50 chance of being correct. However, for those who are not so inclined, the following symptoms, tests, and visual indicators will help in separating the cause from the effect, thereby enabling the most logical deduction.

13.5.1 Membrane Touch Panel Evaluations and Considerations

Examine the ribbon cable for evidence of contaminants or "bleeding" between the lines on the ribbon. While a certain amount of tarnishing is normal and does not in itself mean the touch panel should be replaced, the appearance of black spots or fine web-like lines between the silver conductor traces *are* good signs that the touch panel should be replaced.

Inspect the area of the ribbon tail that slips into the board connector for cleanliness, for sections where the silver has worn off, or for evidence of scratching or hairline cracks. If cleaning is necessary, do so using an alcohol or freon-based contact cleaner. Do not use silicone-based cleaners or lubricants. Gently rubbing the terminals with a soft pencil eraser will also clean them, but, a word of caution: test the effect of the eraser on a non-essential area first! Erasers have been known to clean the silver right off of the ribbon. In many cases the problem can be resolved simply by evenly trimming off about 1/16-inch from the tail of the ribbon, leaving fresh new terminals to assure good electrical contact with the circuit board connector.

A close examination of the front of the membrane touch panel may reveal dents or deep scratches that may be creating a short in certain touch pads. Also, brightening or dimming of the panel-display colons while pressing certain pads is a reasonably good indication that a signal is getting through to the control panel. In that case, try replacing control panel.

Some additional symptoms that indicate a defective key or touch panel are: 1) Only certain pads or groups of pads will respond while others will not. 2) Touching a pad produces a string of characters on the display. 3) One character remains constantly on the display, and disconnecting the ribbon connector from the control board removes it. 4) Some or all pads must be pressed hard or pressed several times to produce a response. 5) The number displayed is different from the one pressed (i.e., press pad #5 and a "9" appears on the display).

A categorized collection of *used touch panels* (or *key units*) is a good idea for testing purposes. Unless they are totally inoperative, *do not throw away used touch panels.* They take up little room and can be used very effectively. For example, suppose you replace a touch panel because the "2" and "4" pads do not work. Label the defective panel appropriately, and save it. One day, a similar oven comes along, with a different symptom: the "start" pad will not respond. Temporarily replace the latter touch panel (with the unresponsive "start" pad) with the used touch panel having the functional "start" pad, and test the unit. If, with the substitute *test touch panel* installed, the oven still will not "start", the problem is likely not in the original touch panel. On the other hand, if the *test panel* "start" pad works, replace the original touch panel. A categorized collection of the touch panels—commercial and domestic—will take much of the gamble out of control panel-touch panel dilemma.

Besides the substitution of a known good panel, the next most certain method of isolating this type of problem is to make continuity checks through each of the touch unit circuits with an ohmmeter. However, without specific data on the matrix configuration of the unit to be tested, this is virtually impossible. Therefore, *Appendix I* contains many of the common matrix diagrams, listed by make and model number, and instructions on how they are tested.

One method of checking a touch panel matrix that works on many *Sharp*-made, as well as other models is as follows: 1) Unplug the oven, remove the cover,

and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S). 2) Disconnect one or both leads from the primary side of the high-voltage transformer so no high voltage will be generated during the test. 3) Remove the flex-tail ribbon from the control board connector. USE EXTREME CAUTION WHEN WORKING AROUND "LIVE" CIRCUITS. 4) Plug in the oven and, cautiously, use a jumper to make *momentary* contact between random points on the control unit connector. This, in many cases, simulates the touch pad (key unit) contacts. 5) If the control panel appears to respond in a relatively normal way, the touch panel is likely the problem. However, assuming this test is compatible with the unit under test, a control panel that fails to respond is probably defective. NOTE: For lack of access, some models may require that the control assembly be removed and placed beside the oven with all harness connections joined.

Many touch panels are shipped with a protective plastic film. If the face of the panel has a bubbled or a hazy appearance it is probably due to this transparent film. Be sure to remove the plastic film before installing the touch panel.

13.6 LOW-VOLTAGE (CONTROL) TRANSFORMER AND TRANSMOTOR CHECKS

A general resistance check of the low-voltage transformer or the transformer part of the transmotor can be performed as follows: Unplug the oven and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S). With an ohmmeter zeroed on its lowest (most sensitive) scale, measure from terminal to terminal as indicated in Figure 13-4. The *Tappan* transformer depicted here is a typical example of a low-voltage transformer. Generally the resistance of the primary winding is approximately 90 to 110 ohms. The control transformer resistance readings of different models may vary somewhat. Transmotors are tested in the same way except, in some cases, the control-voltage output terminals of the transmotor are not so obvious. In those cases, the terminals must first be identified by using the oven schematic or wiring diagram. Normally, as shown in Figure 13-5, one terminal of a transmotor is chassis ground.

Whether testing a transformer or transmotor, measuring the resistance from any terminal on the primary to any terminal on the secondary should produce a reading of infinity. A reading of infinity between any other terminals, however, indicates an open winding and the transformer or transmotor should be replaced.

An operational test may be performed if the proper secondary voltages are known or can be obtained from service literature. If this data is not available, considering the variance of voltage outputs from one model to the next, the results of an operational test may not be conclusive or accurate. Figure 13-5 illustrates the test points and corresponding typical voltages of a transmotor used in a *Litton* model. The secondary voltages shown in Figure 13-6 are very common, and al-

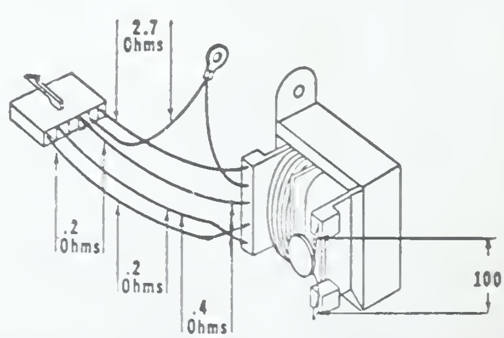
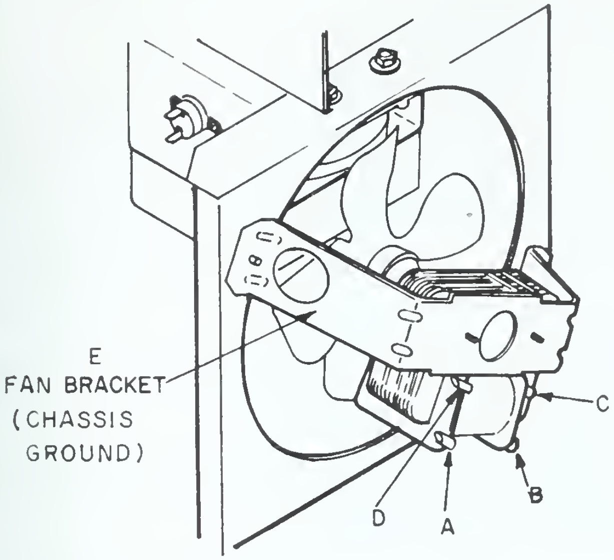
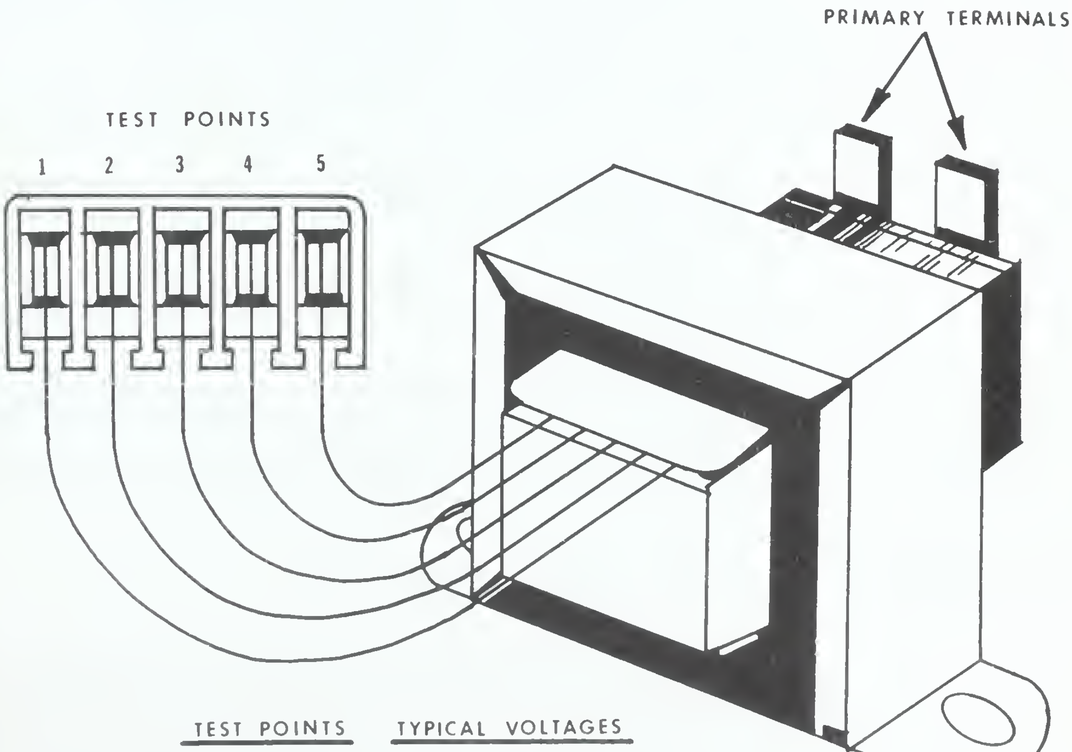


Figure 13-4 Typical low-voltage transformer resistance readings. (Reprinted with the permission of White Consolidated Industries, Inc.)



TEST CHART	
TERMINAL TEST POINTS	VOLTAGE (APPROXIMATE)
A-B	120 Volts A-C
C-E	12 Volts A-C
D-E	12 Volts A-C
C-D	24 Volts A-C

Figure 13-5 Typical transmotor voltages and test points. (Illustration taken from service literature copyrighted 1979 by Litton Microwave Cooking Products. Used by permission.)



TEST POINTS		TYPICAL VOLTAGES
1 — 5	=	24 TO 46
1 — 4	=	13 TO 20
2 — 3	=	2.5 TO 12

Figure 13-6 "Generic" low-voltage transformer. (Courtesy of Michael S. Wagner)

though it is unlikely that the configuration of any one transformer will correspond exactly, an approximate test is possible using this "generic" example.

CAUTION: HIGH VOLTAGES ARE PRESENT AT THE HIGH VOLTAGE TRANSFORMER SECONDARY TAP DURING OVEN OPERATION—OBSERVE EXTREME CAUTION AT ALL TIMES. DO NOT TOUCH ANY COMPONENTS OR WIRING DURING A COOK CYCLE.

1. Unplug the oven, remove the cover, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S) BY SHORTING ACROSS THE TERMINALS WITH AN INSULATED SCREWDRIVER.

2. Set the meter to an AC scale capable of measuring the applied line voltage and attach (with alligator clips) the meter leads to the primary terminals. The harness leads *remain* connected.

3. Apply power to the oven and look for a typically normal reading of 117 volts AC (line voltage may vary). This indicates that the transformer is receiving power.

4. Unplug the oven again and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S). Disconnect the low-voltage transformer connector from the control panel. The secondary outputs are checked in the following manner: Using a small pointed probe, insert either one of the meter probes into the slot at either end (or side) of the secondary connector. This same procedure applies for transformers with terminals, plugs, or pins, instead of a hard-wired connector.

5. Set the meter initially to an AC scale considerably higher than the voltage amounts that are anticipated. This will prevent damage to the meter in the event that an output higher than expected is encountered. Subsequently, the scale may be lowered for a more precise measurement.

BEWARE—HIGH VOLTAGES ARE PRESENT DURING OPERATION!

6. Apply power to the oven. Using the other meter probe, carefully touch each slot (pin or terminal) until all combinations have been measured, noting the voltage reading each time.

7. Compare the readings obtained in the test to those of the "generic" transformer shown in Figure 13-6 to derive an adequate evaluation of the transformer's secondary output.

NOTE: The low-voltage transformer, voltages, and connector numbering depicted in Figure 13-6 do not accurately represent those of any one specific transformer. It is intended merely to illustrate the testing of these transformers and the typical voltages to expect.

13.7 WARM-UP RELAYS AND TIME DELAY CIRCUITS

Warm-up relays (or *time-delay circuits*), found mostly in commercial models, are used to delay the application of high voltage to the magnetron tube until it has warmed up. During the delay (3 to 10 seconds, depending on the model) the tube is warmed up by the application of filament voltage. To extend magnetron life in older commercial models, a *programming relay* provided a circuit that would boost the filament voltage during the warm-up, then reduce the filament voltage during the cook cycle.

If, for example, in a commercial *Litton* 500 or 70 series, after about 8 to 12 seconds the "ready" light does not come on, suspect the 10 second warm-up relay. If,

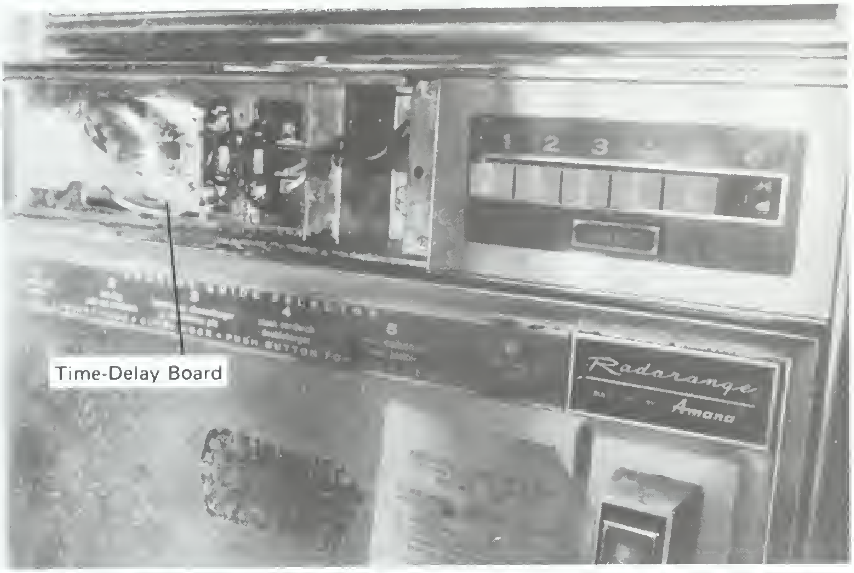
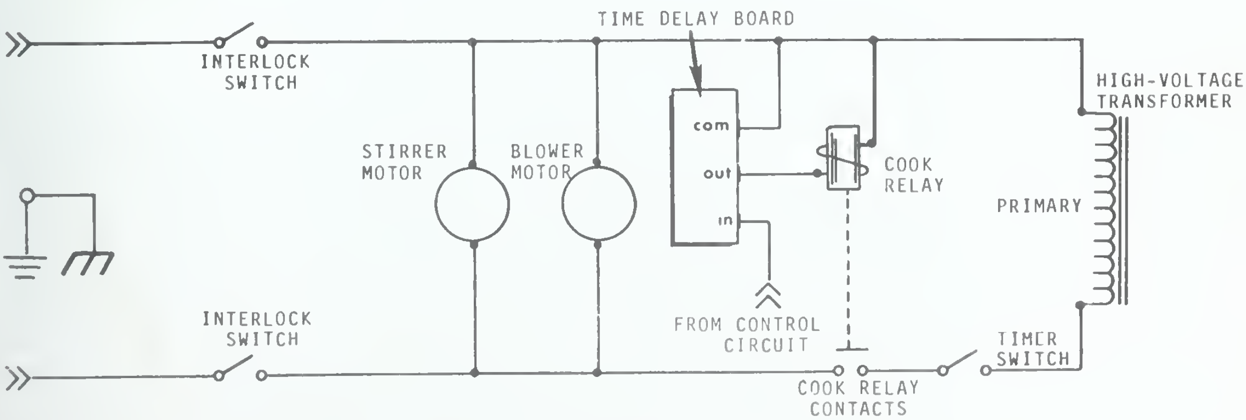


Figure 13-7 Time-delay board.

in a commercial *Amana* (i.e., RC10, RC10A, RC10B, RC10S, and RC14) the oven fails to "click" into the cook cycle after about 3 to 4 seconds, check for a defective time delay board (Fig. 13-7).

To check the warm-up relay or delay circuit, it is first necessary to identify the various terminals. On the old, near-obsolete, thermal-type relays the terminals that correspond to the coil (heater) and to the contacts are usually diagramed on the relay case, and can be checked accordingly. However, the solid state time delay circuit boards that superseded the thermal relays are not so easily deciphered. The oven schematic is usually required in order to identify the *input, output,* and *common* terminals. Refer to the representative schematic of a time delay circuit in Figure 13-8 for the ensuing test. Although the voltage readings and the configurations will vary with different makes, the same principles will generally apply to all delay circuits.



NOTE:
This schematic is generalized and simplified for illustrative purposes, it is not intended to precisely depict any one actual operating circuit.

Figure 13-8 Representative time-delay circuit.

13.7.1 Time Delay Board Test

1. Unplug the oven, remove the cover and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. Gain access to the time delay board, and using insulated clip-type leads, attach an AC voltmeter to the *common* and the *output* terminals. Set the voltmeter to an appropriate scale, depending on the circuit voltages. In this case the anticipated delay relay output is equal to the applied line voltage, so the meter would be set to a scale capable of reading 117 VAC. Ensure that the leads are not touching the chassis or other leads.

CAUTION: HIGH VOLTAGES ARE PRESENT AT THE HIGH-VOLTAGE TRANSFORMER SECONDARY TAP DURING OVEN OPERATION—OBSERVE EXTREME CAUTION AT ALL TIMES. DO NOT TOUCH ANY COMPONENTS OR WIRING DURING A COOK CYCLE.

3. Apply power to the oven, place a water load in the oven cooking cavity and initiate a cook cycle.

4. Assuming this delay circuit provides a 3 to 4 second delay, the meter should initially show anywhere from zero to 50 volts AC. After 3 to 4 seconds the meter reading should swing up to 117 VAC or line voltage.

RESULTS AND SYMPTOMS

If the delay is substantially longer or shorter than normal, the time-delay circuit is defective and should be replaced. An insufficient delay will shorten the life of the magnetron.

If the cook or power relay chatters when energized, or fails to energize (assuming the proper input voltages are available at the delay board), replace the time-delay relay and retest the unit.

NOTE: In delay circuits that employ a triac, such as those used in the commercial *Amana* models mentioned above, the triac may be found split apart. In this case, before the board (or triac, if available as a separate part) is replaced, the circuitry between the delay board's *output* and *common* terminals should be examined for a short.

13.7.2 100 Millisecond-Delay Board Test

Later production commercial *Amana* models (i.e., RC14B, second-generation RC14S) use a *100 millisecond delay board* (Fig. 13-9) in conjunction with a *surge relay*. The circuit functions to delay the application of primary voltage to the high-voltage transformers as illustrated in the simplified schematic of Figure 13-10: The electronic timer initiates the cook cycle by closing the contacts of the *control relay*, which in turn energizes the *power relay* and starts charging the *time-delay network* of the delay board. For the first 100 milliseconds (1/10 of a second) all of the current flows through the *surge resistor*. Finally, after 1/10 of a second, the *triac* on the time delay board conducts (as shown by the dashes) and activates the surge relay. The surge relay contacts close and current flows to the primary of the transformer.

Visual or audible symptoms serve best to evaluate the operation of this delay circuit. If the surge relay chatters when energizing or fails to energize, the time-delay board should be replaced. There should be a 1/10-second delay between the sound of the power relay pulling in (first) and the surge relay pulling in (second). If this does not occur, replace the time-delay board. Repeated power relay or surge relay contact

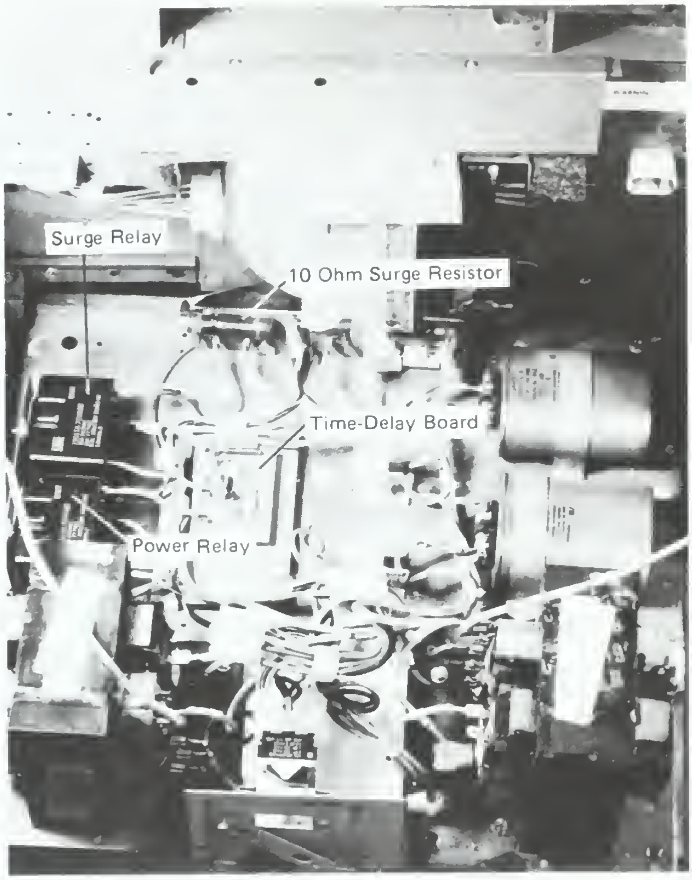


Figure 13-9 Surge monitor components.

failures would point to an erratic time-delay unit. If the triac on the time-delay board is split apart, examine the associated circuitry and wiring for a short before replacing the board.

13.7.3 Surge Relay Check

When the type of failure described above occurs, the power relay and the surge resistor must be replaced. However, the surge relay should also be checked for proper operation. After unplugging the oven and DISCHARGING THE HIGH-VOLTAGE CAPACITOR(S), this test may be conducted in the following manner: Remove the relay from the oven and attach a test cord to the coil terminals. The coil terminals can usually be identified, and the appropriate coil voltage determined, by indications on the relay case. Attach an ohmmeter—zeroed on the R X 1 scale—across the relay contacts, and apply the appropriate coil voltage by means of the test cord. The contacts should close and indicate less than one ohm resistance.

SYMPTOMS AND RESULTS

If a higher resistance is indicated, or the relay fails to energize, replace the surge relay.

> NOTE: As with any surge resistor, if the resistor is burned or discolored from overheating, it is a good indication that the contacts of the surge relay are not closing completely. This could be caused by an open coil, burned contacts, or no drive voltage from the delay board. If, after replacement, the surge resistor

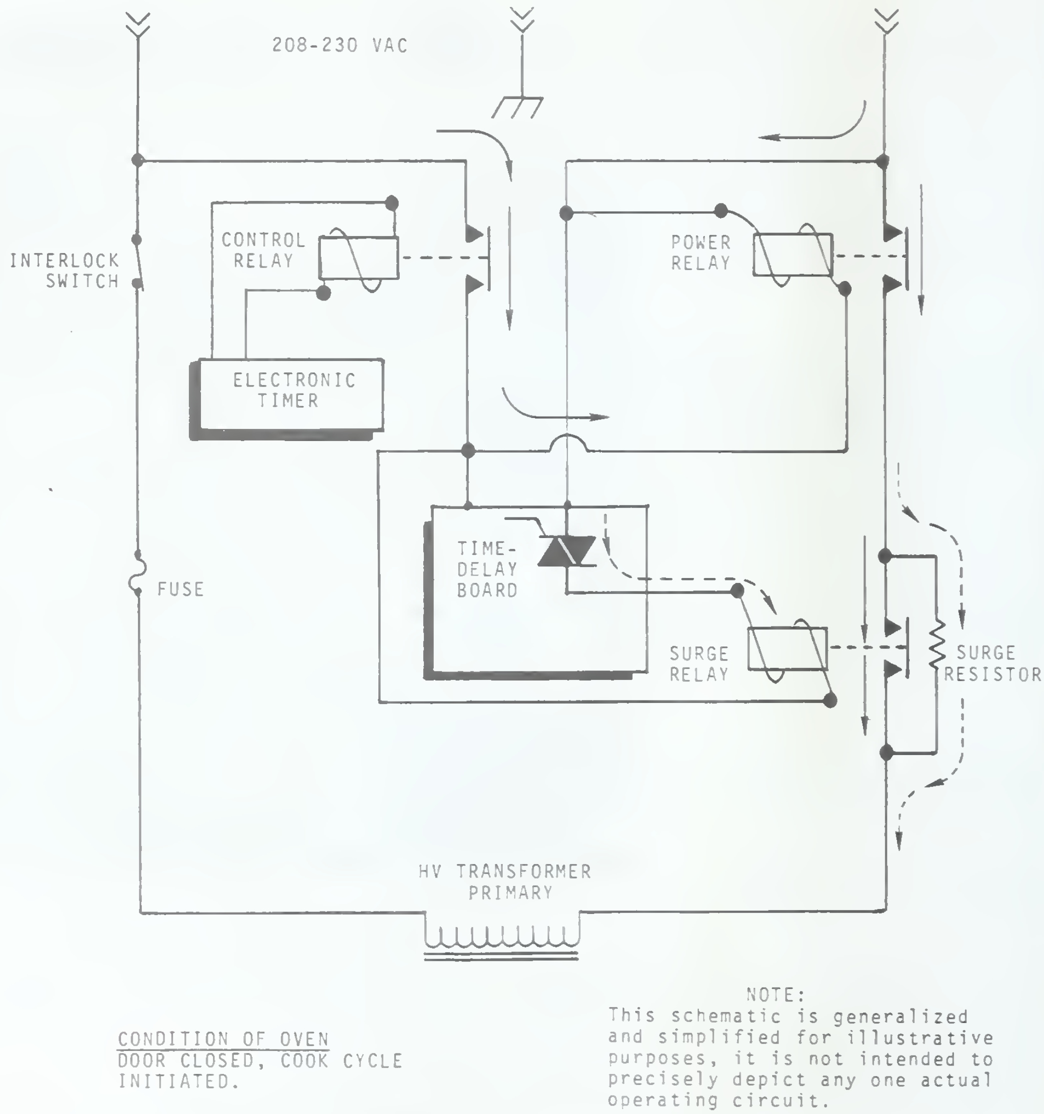


Figure 13-10 Simplified delay circuit.

shows signs of overheating, the surge relay or the time-delay board should be suspected.

13.8 START-UP, SHUT-DOWN, AND HOLDING RELAYS

Commercial *Sharp* and many commercial and domestic *Litton* models are among some earlier-production units that initiate a *start-up* sequence when the oven door is opened. This function involves a *holding relay* (or circuit), and a *shut-down relay* (which returns the oven to the standby mode after a specific period of non-use, usually about 60 seconds). Figure 13-11 shows, from left to right; a domestic-model holding relay, a commercial-model 10-second warm-up relay, and a commercial-model 60-second shut-down relay. In subsequent models these functions are combined in one relay or relay circuit.

These components are best checked by simply monitoring and verifying their functions, and then in some cases, additional tests may be made. For example: In virtually all ovens that use an automatic *start-up* function, the operation is initiated

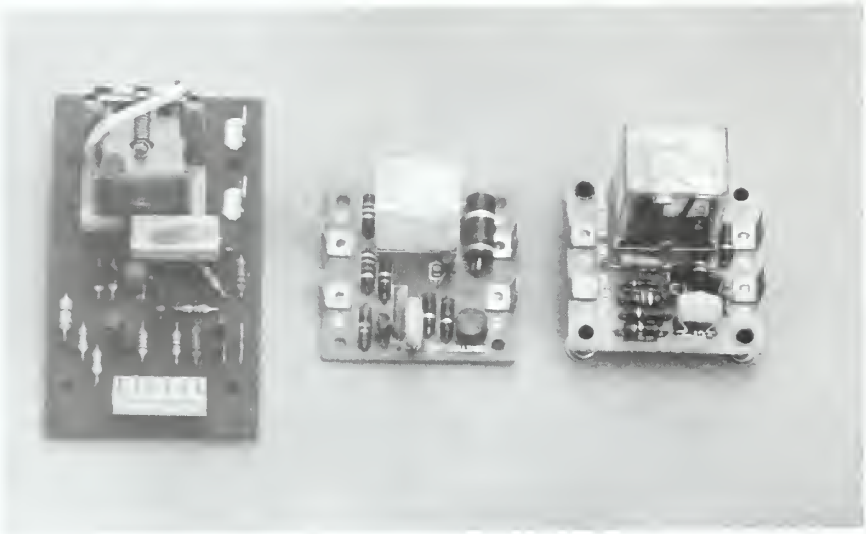


Figure 13-11 Holding, warm-up, and shut-down relays.

by a door interlock "start" switch. If, for instance, a commercial *Sharp* model fails to come up to the idle mode when the door is opened or closed. (Figure 13–12 shows the location of a *start switch* in many *Sharp* models. As you face the front of the oven, it is located toward the bottom left-hand side, and is momentarily activated by a door cam arm as the door opens from a closed position, *or* closes from an open position.) The *start switch* should be checked as follows: Unplug the oven and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S). Then, disconnect one of the leads to the start switch and with an ohmmeter, check for continuity between the *common* and *normally open* terminals. Pressing the switch actuator should produce continuity, releasing it should show infinity. If abnormal readings are obtained, replace the switch. If the switch is found to be normal, verify its proper adjustment, and examine the wiring between the switch and the start-up circuit.

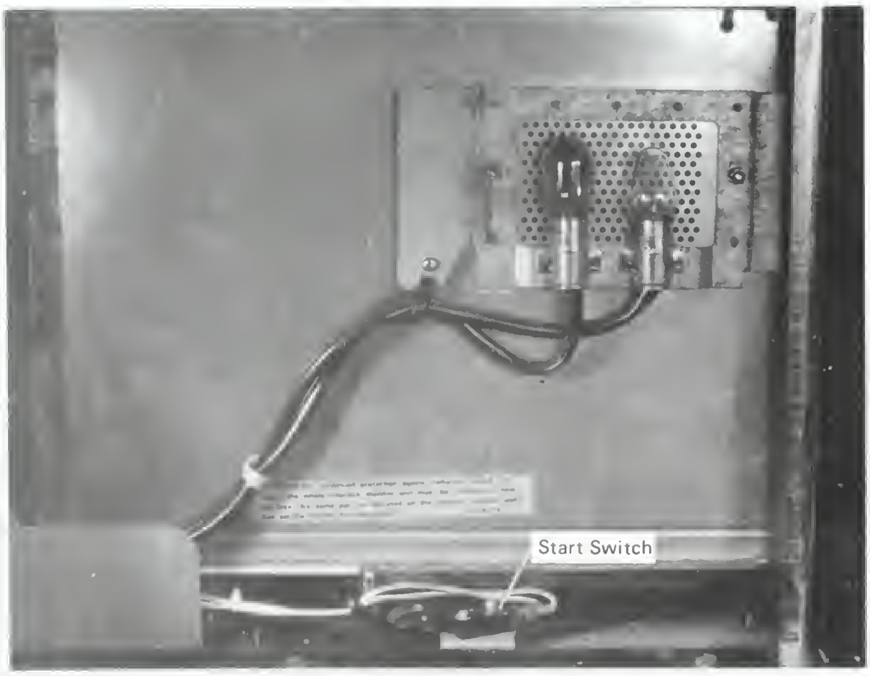


Figure 13-12 Common start switch location.

3.8.1 Load Resistor Check

The load resistor, used in conjunction with the holding relay in many of *Litton's* commercial ovens (see Figs. 8-22 and 8-23), is checked as follows: unplug the oven, remove the outer case, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S). Find the load resistor which is located either just behind the control panel near the light bulb, or toward the right rear side by the blower motor. Remove the wire from one end of the load resistor and attach one meter lead to that terminal. Zero the ohmmeter on the R X 10 scale and measure the resistance across the resistor to the other terminal. The resistance should be 775 ohm +/− 10%.

13.8.2 Associated Symptoms

Symptoms indicating defects in a start-up, holding, or shutdown function are: 1) A momentary attempt to go into the idle condition as the door is opened, but fails. 2) The oven comes up to the idle mode when the door is opened, but reverts back to standby when the door is closed. 3) The oven erratically shuts down during a cook cycle. (Temporarily bypassing the holding relay will accommodate a frantic restaurant owner until permanent repairs can be made. Until then, the oven should be unplugged or turned off when not in use.) 4) The unit stays in the idle or ready condition and never shuts down.

13.9 CHECKING RELAYS IN GENERAL

With the numerous functions, applications, contact arrangements, and coil voltages of the various relays used in microwave ovens, a general checkout procedure is here provided which will enable a fairly complete evaluation of most relays.

A relay should be suspected if the function it controls is not operating. For example: A *holding relay* should be checked if an oven fails to remain in the idle mode. The *auxiliary relay* or *oven relay* in a *Litton* model should be tested if the blower and stirrer motors do not operate. The *cook relay* should be examined if the oven fails to enter the cook mode, or cooks continuously. The *power relay* should be suspected in a *Quasar* or *Panasonic* oven that will not "start", or will operate only while the start button (or pad) is pressed. And, the *heater relay* in *Sharp* convection models should be checked if the convection cooking temperature fails to rise.

13.9.1 General Relay Checkout Procedure

1. Unplug the oven, remove the outer case, and *DISCHARGE THE CAPACITOR.*

2. Locate the suspected relay and perform either one or both of the following tests. The first procedure involves an operational test, the second is a visual and continuity check.

TEST #1

A. Ascertain the value and type (AC or DC) of relay drive voltage from the oven schematic or from the specifications listed on the relay case.

B. Using a voltmeter capable of measuring the anticipated relay drive voltage, carefully clip the test leads to each coil terminal (coil terminal locations are usually diagrammed on the relay case). All harness leads remain connected. Be sure to insulate the meter probes so as not to create any additional problems.

CAUTION: HIGH VOLTAGES ARE PRESENT AT THE HIGH-VOLTAGE TRANSFORMER SECONDARY TAP DURING OVEN OPERATION–OBSERVE EXTREME CAUTION AT ALL TIMES.

USE CLAMP-ON TYPE CONNECTORS WHEN MAKING OPERATIONAL TESTS.

DO NOT TOUCH ANY COMPONENTS OR WIRING DURING A COOK CYCLE.

C. Place a water load in the oven, keep hands clear, and apply power to the unit. Initiate the function to be checked and observe whether or not the appropriate drive voltage is being supplied to the relay.
   (1) Visually examine the relay during operation for arcing or sparking of the contacts while opening or closing. Severe sparking may be caused by an open surge resistor.

D. If the appropriate drive voltage is not present, the associated wiring and control panel circuitry should be examined. If drive voltage is present, but the relay fails to activate, replace the relay. If drive voltage is present and the relay does activate but corresponding functions are still inoperative, perform the following check on the relay contacts:
   (1) Determine the location of the contact terminals as diagrammed on the relay case. Carefully remove all harness leads except for the coil leads.
   (2) Zero an ohmmeter to the lowest scale and attach the test leads to the terminals of each set of contacts to be tested.
   (3) Apply power to the oven and initiate the operation that energizes the relay to be checked. Observe the ohmmeter for the following normal indications: With the relay energized, the meter should indicate zero ohms (or continuity) across the N.O. (normally open) contacts. And, the meter should show infinity across the N.C. (normally closed) contacts. The opposite should be true with the relay de-energized.
   (4) If the relay fails these tests in any respect it should be replaced.

Note: The tests just outlined may also be performed by removing the relay from the oven and using a bench power supply to provide the appropriate coil voltage.

TEST #2

A. Carefully remove the leads from the relay coil terminals and, using an ohmmeter zeroed to the appropriate scale, measure across the coil for continuity. Following are some typical, although quite disparate, examples of coil resistances (values vary with different brands, and all values are approximate):

   Litton Holding Relay .... 50 Ohms
   Litton Auxiliary Relay .... 1200 Ohms
   Litton Cook Relay .... 250 Ohms
   Litton "Jet-Wave" Cook Relay .... 178 Ohms
   Litton "Jet-Wave" Latch and Lock Relays .... 475 Ohms
   Litton "Jet-Wave" Heater Relay .... 140 Ohms
   Amana RC 10B Power Relay .... 1700 Ohms
   General Electric Power Relay .... 190 Ohms

Whirlpool/Litton Oven Relay......................300 Ohms
Magic Chef M41A-7P Operating Relay............2600 Ohms
Magic Chef M41A-3 Operating Relay............16000 Ohms
Sharp Cook or Heater Relay......................170 Ohms
Tappan Surge Relay.........................520–660 Ohms
Tappan Surge Relay (probe models)...............2.4 Ohms

B. If no continuity is read through a relay coil, replace the relay.

NOTE: Many *solid state* relays are designed with an internal *full-wave bridge rectifier* which is usually shown on the associated schematic diagram. While an ohmmeter will detect a relay with a shorted *bridge,* the ohmmeter will erroneously show a good coil as open. So, the best way to check these types of relays is by applying the appropriate voltage to the coil; if the relay closes, the bridge and the coil are good.

C. To test the continuity of the contacts while the relay is removed from the oven, a separate power supply may be used to activate the relay, as noted above. Or, in many cases the relay can be manually actuated by pressing down on a "test button", if so equipped, or simply depressing the relay arm so the contacts come together. The continuity of the contacts may then be verified with an ohmmeter.

D. Unless otherwise indicated, a resistance check from any relay terminal to chassis ground, with the harness leads removed, should show infinity.

E. Visually examine the physical position of contacts during closure. Refer to Figure 13-13: The moving arm should meet the stationary arm with a slight sweeping (or cleaning) action of the contacts. The moving contact should come to rest squarely against and centered upon the stationary contact with slight over-travel. In other words, as the contacts meet, the moving arm should continue its forward motion to just beyond the point of initial contact, so that the stationary arm is bent slightly backwards.

(1) A relay whose contacts have stuck closed should be replaced rather than merely pried open and cleaned. A burned, cracked, or dis-

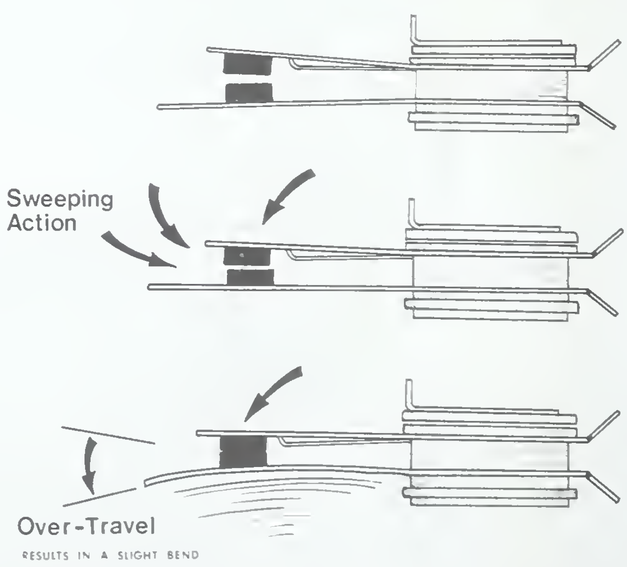


Figure 13-13 Proper relay contact closure. (Courtesy of Michael S. Wagner)

colored surge resistor (Fig. 13–14) indicates that its corresponding relay contacts are burned, pitted or otherwise not closing properly.

(2) Visually examine the coil for evidence of overheating. A darkened or discolored area may be an indication of a short in the winding. Many relays have a fuse of some sort embedded in the winding; if this fuse is open the relay must be replaced.

(3) Inspect the contacts themselves for pitting, marring, or melting from being "welded" together. Relays with severe contact deterioration of this nature should be replaced.

13.10 OUTPUT POWER-CONTROL COMPONENT TESTING

Remember that the output power is typically controlled by cycling the magnetron tube on and off in a controlled fashion. Recall too, that this is done in one of two ways: on the *primary side* of the high-voltage transformer, or on the *secondary side*. Primary side control components will be considered first.

13.10.1 Primary Side Power-Control Component Testing

Beginning with the basic electro-mechanical controller (also referred to as variable controller and percent timer), testing may be accomplished in two ways. Note that the first test involves by-passing the controller and monitoring the oven's operation. It should also be noted at this point that any of the following tests that by-pass the controller should be performed *only if the problem is that the oven does not heat.*

TEST #1

1. Unplug the oven, remove the outer cover, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. Using the schematic or wiring diagram, determine which terminals are the *contacts* of the controller and disconnect those leads. An example is the *Tappan* controller and partial schematic subsequently shown in Figure 13–15. Terminals #2 and #4 are the contacts, so the leads attached to those terminals would be removed.

3. Connect the two wires just removed from the controller together with an in-line connector or a jumper wire.

CAUTION: HIGH VOLTAGES ARE PRESENT AT THE HIGH-VOLTAGE TRANSFORMER SECONDARY TAP DURING OVEN OPERA-

Figure 13–14 Cracked surge resistor.

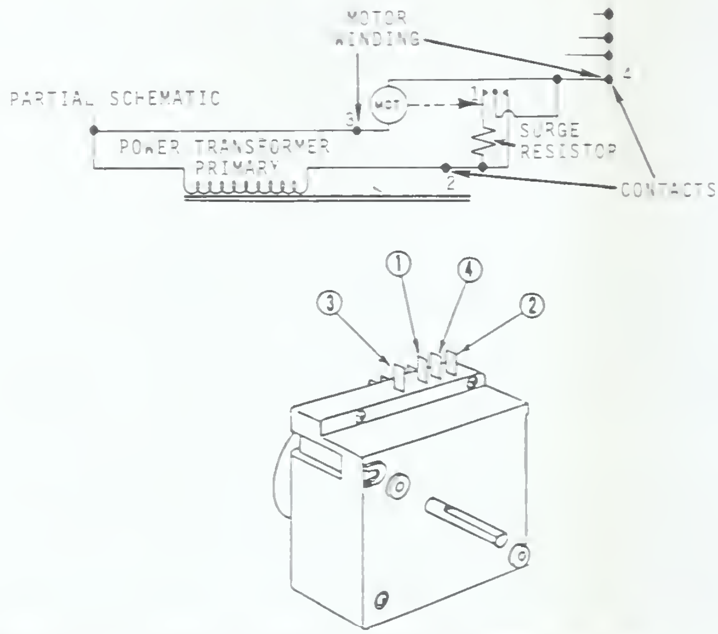


Figure 13-15 Tappan variable controller. (Reprinted with the permission of White Consolidated Industries, Inc.)

TION—OBSERVE EXTREME CAUTION AT ALL TIMES WHILE WORKING AROUND "LIVE" CIRCUITS.

DO NOT TOUCH ANY COMPONENTS OR WIRING DURING A COOK CYCLE.

4. Place a water load in the oven, apply power and perform an oven operational test to determine if the unit is producing a full power output.

5. If the abnormal condition disappears with the controller by-passed, the controller is defective and should be replaced. If the problem still exists, check elsewhere.

The second test checks the resistance of the motor windings and then monitors the operation of the internal switch contacts.

TEST #2

1. Unplug the oven, remove the outer cover, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. Identify and remove the wires going to the motor terminals. In Figure 13–15 the motor terminals are #3 and #4.

3. Connect an ohmmeter to the vacated motor terminals and measure for about 2500 ohms. A reading of infinity (open circuit) here denotes a defective controller motor.

4. With the motor leads still disconnected, attach a 115 volt test cord (cheater cord) to the just-measured motor terminals.

5. Set the ohmmeter on the R X 1 scale and connect the meter leads across the contact terminals. In Figure 13–15, one meter lead would be connected to terminal #2, and the other to terminal #4.

6. Plug in the test cord and observe the meter as the motor runs. With the controller set to about "medium" or mid-range, the meter should recurrently show *continuity* then *infinity* and then *continuity* again. This reflects the cyclic opening and closing of the internal controller contacts.

7. If the contacts fail to open or close, replace the controller.

NOTE: A cracked, burned, or discolored surge resistor associated with the controller is a strong indication of failing controller contacts, even though the surge resistor may not yet be opened.

13.11 SOLID STATE CONTROLLERS

Operational tests on these controllers are made in much the same way as the preceding by-pass test on the electro-mechanical controller. In this case the electronic switching circuitry is by-passed, thereby eliminating the controller from the system, along with any problems it may be causing. Keep in mind that by-pass tests are necessary only if the oven is not heating

1. Unplug the oven, remove the outer cover, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. Using the schematic or wiring diagram, identify the *input* and *output* terminals of the solid state controller. There may be several terminals on some controllers. If schematic information is unavailable, the input and output terminals can be isolated by tracing out and eliminating the *low-voltage input* terminals, and the *probe loop* terminals (if applicable). Normally the remaining terminals will be the *input, output,* and *common* terminals. Figure 13-16 illustrates a common controller with the input and output terminals identified according to the schematic. ("Input" and "output" are etched right on the printed circuit board, along with the terminal numbers, on many controllers.)

3. Remove the leads from the input and output terminals and connect them together with a jumper wire or an in-line connector. Insulate the connection if necessary to prevent an electrical short.

Note: Controllers with triacs such as the one pictured in Figure 13-17 may be by-passed by placing an insulated jumper wire from MT1 to MT2 as shown. In some triac designs of this nature, the triac body serves as the MT2 terminal. In such cases the test jumper lead would connect from the MT1 terminal to the heatsink or metal plate on which the triac is mounted.

CAUTION: HIGH VOLTAGES ARE PRESENT AT THE HIGH VOLTAGE TRANSFORMER SECONDARY TAP DURING OVEN OPERATION—OBSERVE EXTREME CAUTION AT ALL TIMES WHILE WORKING AROUND "LIVE" CIRCUITS.

DO NOT TOUCH ANY COMPONENTS OR WIRING DURING A COOK CYCLE.

4. Apply power to the oven and initiate an operational test at full power. Determine whether or not the oven is operating normally at full power.

5. If the abnormal conditions still exist with the controller by-passed, the problem lies elsewhere. However, assuming that the supply voltages are normal, and the external probe circuitry (if applicable) is operational, *normal* full power operation with the controller out of the circuit indicates a defective controller.

13.12 TRIAC TESTS

The following resistance checks will detect most shorted or open triacs. However, some triacs shown as acceptable by this procedure may in fact be breaking down under the stress of actual circuit operation. Additional procedures that check the triac under operation will be outlined following these non-operational tests. *Test 1* applies to the various types of triacs subsequently pictured in Figure 13-18 which, for the purposes of this test, will be referred to as Type "A" triacs. This group of triacs comprises the majority of the triacs presently in use.

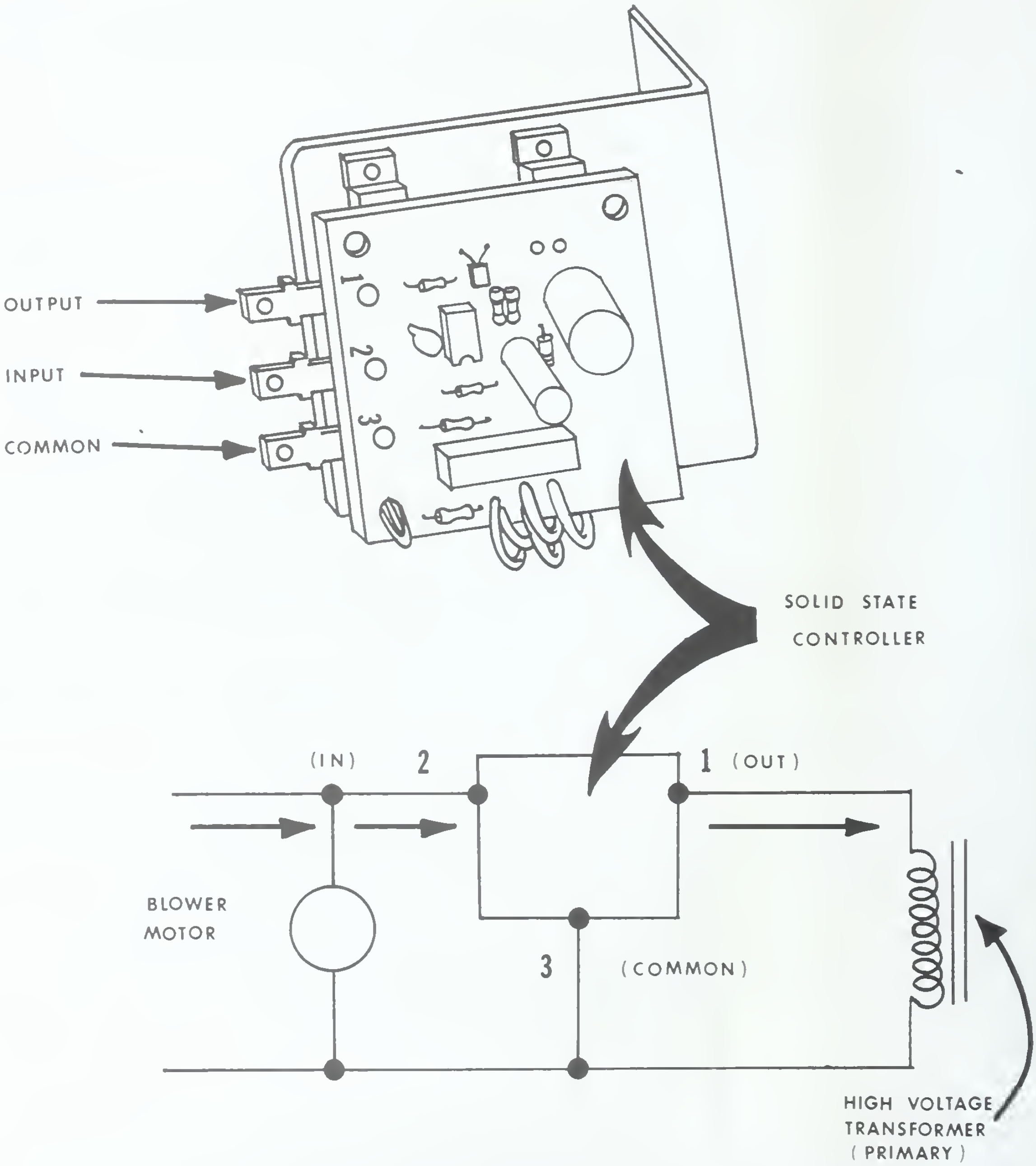


Figure 13-16 Typical solid state controller. (Courtesy of Michael S. Wagner)

1. Unplug the oven, remove the outer case, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. Locate the triac and remove all leads that are attached to it. For the first measurement of TEST 1, set the meter to a resistance scale capable of measuring about 40 ohms. Rather than a simple continuity check here, a *specific* resistance value is sought, so it is necessary to *zero* the meter. Do so by bringing the two meter probes into contact with each other. While the probes are touching each other, adjust the 'zero ohms' or "zero adjust" knob on the meter until the meter pointer (needle) aligns with the "O" (zero) mark on the ohms scale. (If this calibration cannot be achieved, the meter batteries are weak and should be replaced.) The

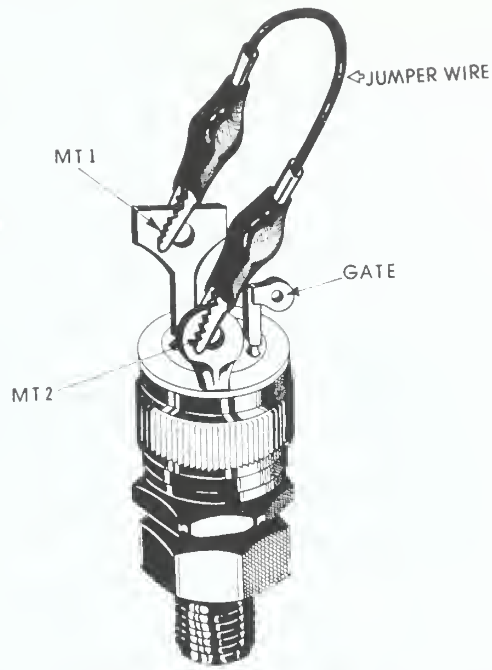


Figure 13-17 Triac by-pass. (Courtesy of Michael S. Wagner)

second series of measurements of Test 1 anticipates readings of infinity so the meter should be set to its highest resistance scale. In each test refer to Figure 13-18 for triac terminal identification and measure across the terminals in each direction as indicated in the following chart.

NOTE: The readings listed are approximate and may vary with manufacturer.

TEST #1

From Terminal	*To Terminal*	*Acceptable Range*	*With Leads Reversed*
Gate	(M)T1	10-200 OHMS	10-200 OHMS
	(set meter to R X 10,000 or higher scale)		
(M)T1	(M)T2	INFINITY	INFINITY
(M)T2	GATE	INFINITY	INFINITY
(M)T1, (M)T2, and GATE	CHASSIS GROUND	INFINITY	INFINITY

13.12.1 Results and Symptoms

A triac SHORTED from (M)T1 to (M)T2 will cause an oven to cook at full power regardless of the power setting. In many models, the circuit provided by the shorted triac will supply a continual voltage to the primary of the transformer so that the magnetron goes into oscillation as soon as the oven is brought up to an idle mode or, in some models, merely plugged in. The complaint will be any or all of the following: (1) a low humming or growling sound when the door is closed, (2) a broken or blistered cooking shelf, (3) a tripped magnetron, TP, or cavity thermal protector, (4) the oven overcooks everything on lower power settings.

A complaint of a loud rumbling sound just before the oven went "dead" suggests that the triac has shorted to ground, or is intermittently breaking down under load and shorting to ground. Sooner or later, and usually during a cook cycle, this condition causes the line fuse to open. And, as was the case with the triac

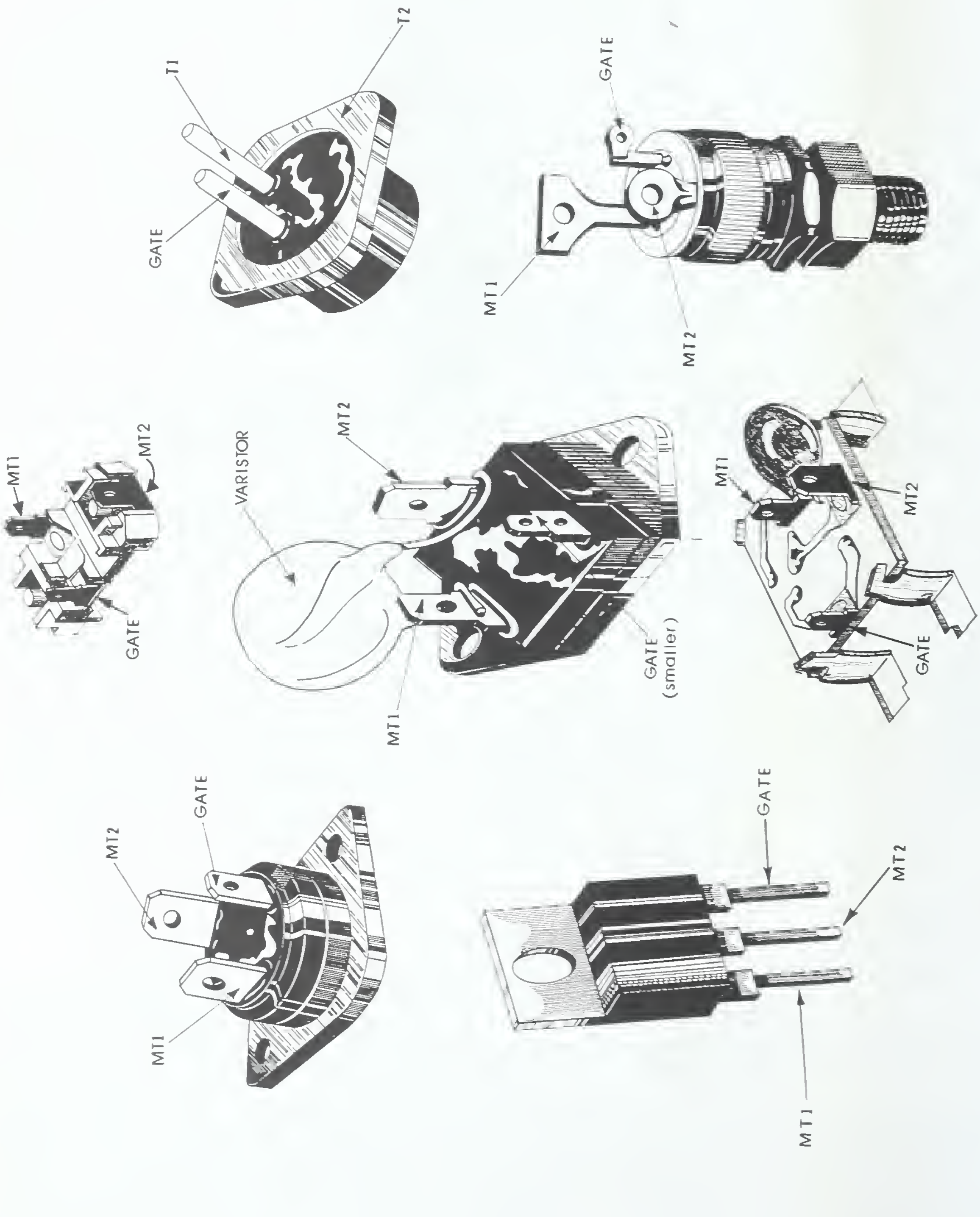


Figure 13-18 Triacs test-referenced as type "A". (Courtesy of Michael S. Wagner)

pictured in Figure 13-19, this failure is sometimes accompanied by the pungent odor of burning electrical insulation. In some cases electrical transients are to blame and the installation of a varistor or snubber across (M)T1 and (M)T2 may help. However, even though the triac may test normal with an ohmmeter, the most conclusive solution is to replace the triac. If the fuse has blown before, and for no apparent reason, it is especially advisable to replace the triac.

A triac short involving the gate input may cause damage to interfacing components such as the control panel. Usually accompanied, again, by a pronounced electrical burning odor, the line voltage bleeds over to the gate input and feeds back up to the control panel. When this occurs the control panel circuit that generates and governs the gate signal is almost always damaged or destroyed. Many manufacturers include a notice that warns of that possibility and suggests that the triac be checked for such a defect before installing a new control panel. More than a few *new* control units have been laid to waste by a perniciously defective triac. There is another possible unpleasant consequence of a shorted triac that can turn a customer's approval on an estimate into an annoyed "scrap it!" This occurs when a shorted triac is replaced only to discover that the highly-expensive control panel was an unexpected casualty of the triac's failure.

These costly predicaments can be avoided to a large extent by, in the first instance, visually inspecting the defective printed circuit board *before* installing a new one. Clues that indicate a possible shorted triac are: evidence of overheated or burned components (particularly resistors), and an edge connector, terminal, or circuit board track that is discolored, raised, or burned. In addition, there are certain symptoms, coincident with the failure of the control board, that may suggest either a defective triac, or one that has been weakened to an extent that it should be replaced. These symptoms include: a low hum at the end of a full-power cooking cycle, or *during* a lower-power cooking cycle, followed by the line fuse opening. Also, a low pitched 60-cycle rumble during a cook cycle could be caused by a failure in the gate shaping circuit of the control panel that causes the triac to turn on and off at 60 times a second. In these cases both the panel and the triac should be replaced. In the second instance, verify the fact that the control panel is producing a proper gate voltage (the procedure is outlined in the following paragraph, *Section 13.12.2*) before assuming that the triac is the only problem and thus finalizing the estimate as such. The temporary substitution of a known good triac may be more convenient in some cases.

If the triac is OPEN the oven will not heat. Very often, however, the open condition was preceded by a shorted condition. So, again it would be wise to verify a proper gate voltage output from the control panel before locking yourself into an estimate.

13.12.2 Verifying Proper DC Gate Voltage

Test 2 will measure the DC gate voltage on units that employ *Type "A"* triacs (refer to Fig. 13-18). If there is a question as to the applicability of this test to a particular

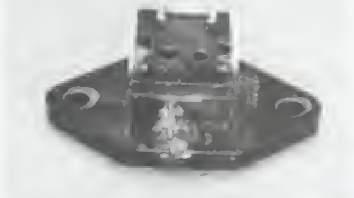


Figure 13-19 Shorted triac.

triac, proceed with caution, being alert for inconsistencies and being prepared to consult either an alternate test method or the appropriate service manual.

TEST #2

1. With the oven unplugged, uncovered, and the CAPACITOR(S) DISCHARGED, remove the HIGH-VOLTAGE LEAD that connects the high-voltage secondary tap to the otherwise unoccupied terminal of the high-voltage capacitor (see Fig. 12-2).
2. Disconnect the harness lead that is connected to the triac gate terminal.
3. Set the meter to a scale capable of measuring 30 volts DC and connect the positive meter probe to the MT1 terminal and the negative (or common) probe to the lead disconnected from the triac gate terminal.
4. Isolate all connections to prevent a possible short.
5. Bring the oven up to an idle condition by plugging it in and either opening and closing the door or turning the oven "on", depending on the make and model. *Do not* put the oven into a cook cycle yet.
   A. At this point there should be a reading of zero volts on the meter; an abnormal reading here implies an inappropriate output of gate voltage and the control panel should be replaced.
6. Put the unit into a cook cycle. **WARNING: STAY CLEAR OF HIGH VOLTAGE.**
   A. If a normal reading of 7 to 18 volts DC is indicated, the gate voltage generating circuit of the control panel is operating normally.
   B. An abnormal reading suggests either a defective control panel or a faulty connection between the triac and control panel.

13.12.3 Gate-Firing Capability Check

Test 3 is a simple ohmmeter test that will, to an extent, evaluate the gate-firing capabilities of most triacs. If, in using this test, inconclusive results are obtained on a particular triac or triac module, then an alternate test method may be advisable.

TEST #3

1. Unplug the oven, remove the outer cover, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. Isolate the triac by carefully removing all harness leads attached to it (if there is a soldered-in varistor, assuming it is in good condition, it may remain attached).

3. Connect the negative meter lead to (M)T1 (cathode) and the positive meter lead to (M)T2 (anode).

4. With the meter set to the R X 1 scale, *momentarily* short the gate to (M)T2. The meter needle should swing to a normal reading of approximately 15 to 50 ohms and stay there. The momentary connection from the gate to MT2 should be sufficient to turn "on" the triac, so when that brief connection is removed the continuity from MT1 to MT2 should remain. This demonstrates the triac's "on" condition and should hold steady until the meter leads are removed from MT1 and MT2.

5. Now, remove the leads from (M)T1 and (M)T2 then reconnect them. The meter should now show no reading.

6. Reverse the meter leads on (M)T1 and (M)T2, then once again briefly connect the gate to (M)T2. Duplicate results should be noted.

13.12.4 Results

Assuming the triac under test is compatible with this procedure, any abnormal indication would suggest a defective triac.

13.13 TRIAC OPERATIONAL TEST

Test 4 provides an operational check for *Type "A"* triacs (refer back to Fig. 13-18). Once having verified that the triac is receiving the proper gate voltage, this test will establish the ability of the triac to turn on and off during circuit operation.

TEST #4

1. Unplug the oven, remove the outer case, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).
2. Completely *REMOVE* the HIGH-VOLTAGE LEAD that connects the transformer secondary tap to the otherwise-unoccupied capacitor terminal that is opposite the one to which the diode is connected (see Fig. 12-2).

WARNING: HIGH VOLTAGE IS PRESENT AT THIS HIGH-VOLTAGE SECONDARY TAP DURING A COOK CYCLE. DO NOT TOUCH ANY OVEN COMPONENTS OR WIRING DURING OVEN OPERATION. ATTACH METER LEADS WITH CLAMP-ON TYPE CLIPS WHEN MAKING OPERATIONAL TESTS.

3. Leave the triac harness leads *connected* and set the voltmeter to measure 120 volts AC. Attach the meter leads—using alligator clips—to triac terminals (M)T1 and (M)T2.
4. Plug in the oven and bring it to an idle condition. With the triac "off" a normal indication of 120 volts AC should be read across (M)T1 and (M)T2.
   A. A voltage substantially less than 120 volts but more than 10 volts means that the defective triac is breaking down and attempting to conduct. A reading of zero volts suggests either a shorted triac or an unsolicited gate signal from a malfunctioning control panel.
5. Put the oven into a cook cycle and observe the reading on the meter.
6. A normal reading of less than 5 volts AC indicates that the triac is conducting normally.
   A. If the proper gate voltage has been confirmed, then an abnormal reading denotes an open triac. Replace the triac and re-test the unit.

13.13.1 Replacement Considerations

A thermal (heat-sink) compound, when supplied, should be spread evenly in a thin coating onto the new triac base. This will insure good heat transfer to the triac mounting structure.

13.14 AMANA SOLID STATE RELAY (TRIAC) TEST

Amana commercial models in the RC and RV series use a solid state relay or triac such as the one subsequently pictured in Figure 13-21. There are two methods to test this component, the first is as follows:

1. Unplug the oven and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S). Also, GROUND THE *BY-PASS (RF) CAPACITORS* on the magnetron by touching the blade of an insulated handled screwdriver to the magnetron housing and, simultaneously, to each magnetron terminal. Gain access to the solid state relay by unsecuring and sliding out the high-voltage power supply tray as demonstrated in Figure 13-20. This tray lifts, then pulls out toward the rear of the unit. Be careful, the tray is heavy, and often greasy.
2. Set and zero the meter on the R X 1 scale.
3. Refer to Figure 13-21. Attach the negative lead to the terminal marked "– 4", and the positive lead to the terminal marked "+ 3".
4. The result of step 3 should be a reading of approximately 320 ohms.
5. Reversing the meter leads should produce a reading of approximately 140 ohms across terminals "– 4" and "+ 3".
6. After setting the meter up to the highest resistance scale, attach the leads to the terminals marked "1 line" and "load 2".
7. The reading in each direction should be infinity or an open circuit.

The second method for testing this solid state relay requires a 12 volt DC power supply.

1. Disconnect all wiring from the solid state relay (be sure to make a note of the wire locations).
2. With the meter on the R X 1 scale attach the leads across the "1 line" and "load 2" terminals.
3. Connect the negative lead from a 12 volt DC power source to the negative ("– 4") terminal of the solid state relay input.
4. Connect the positive lead from the power source to the positive ("+ 3") input terminal.
5. With the 12 volt DC supply turned on, the ohmmeter across terminals 1 and 2 should show continuity (less than 1 ohm).
6. Turning off the 12 volt DC supply should produce an ohmmeter reading of *no* continuity or an open circuit.

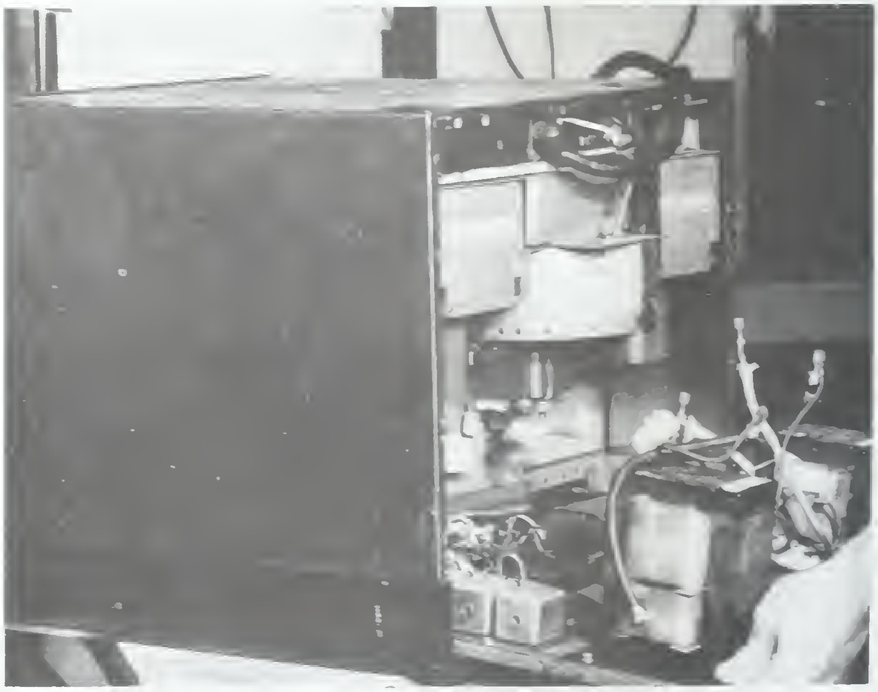


Figure 13-20 Removal of the power supply tray.

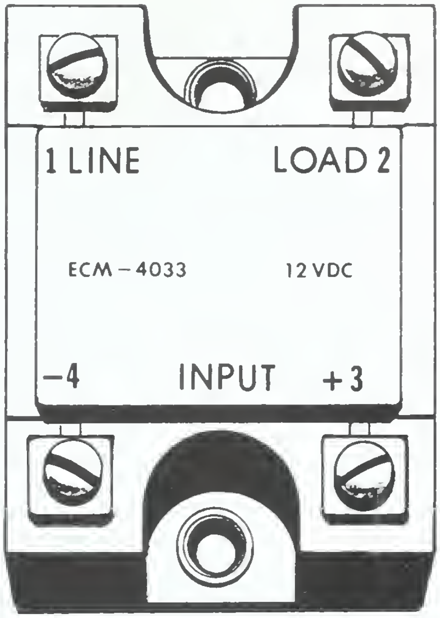


Figure 13-21 Solid state relay.

13.15 TRIAC MODULE TEST

Triac modules are comprised of at least one triac, surge and spike protection, and various other supportive components. Generally, when a triac module fails, it does so in the same manner, with the same symptoms, and under the same circumstances as a triac.

1. Unplug the power cord, remove outer case, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. Remove the high-voltage lead that connects the capacitor to a transformer secondary tap (see Fig. 12-2).

WARNING: HIGH VOLTAGE IS PRESENT AT THIS HIGH-VOLTAGE SECONDARY TAP DURING A COOK CYCLE.

DO NOT TOUCH ANY OVEN COMPONENTS OR WIRING DURING OVEN OPERATION.

OBSERVE EXTREME CAUTION AND USE CLAMP-ON TYPE CONNECTORS DURING OPERATIONAL TESTING.

3. Set the meter to a scale capable of measuring 120 volts AC and, leaving triac and transformer harness leads connected, attach the meter leads (using alligator clips) to the primary terminals of the high-voltage transformer.

4. Apply power to the oven and initiate a cook cycle.

5. Note the voltage reading on the meter.

13.15.1 Results and Symptoms

If a lower power setting was selected, a normal indication should show the meter switching between 0 and 120 volts AC as the gate signal cycles the triac on and off. With a full-power setting, a normal indication of a constant 120 volts AC should be read.

Assuming normal line voltage is available (i.e., 120 Volts AC), a voltage

reading at the primary of the transformer that is substantially less than the line voltage would strongly suggest a defective triac. A constant 120 volts during a lower power cook cycle suggests a shorted triac module. A shorted module will cause the oven to cook at full power regardless of the power setting. In many models a shorted triac will allow the application of primary voltage to the transformer so that the magnetron will hum into oscillation whenever the oven is plugged in, turned on, or when put in the idle mode.

An indication of zero volts (or no reading) across the primary of the transformer, in which case the oven will not heat, suggests the likelihood of an open triac module. The next step is to verify the triac module drive voltage.

A replacement module at this point may save some time. If a substitute module restores proper operation to the unit, it may then be concluded that the original triac is defective. Normal oven operation also verifies that the proper triac-drive voltage is present. While subsequent abnormal operation will likewise reveal an absence of the proper gate voltage, it will not disclose a gate voltage that is of insufficient amplitude to "fire" the triac. This can only be detected by measuring the gate voltage.

13.15.2 Gate Voltage Verification

This test will measure the gate voltage output from the control panel to the triac module in units that use an *AC* coupled gate signal. To avoid damage to the module, follow the instructions carefully and, if in doubt as to the applicability of this test to the triac in question, refer to an alternate test method or to the appropriate manufacturer's current servicing literature.

1. Unplug the power and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).
2. Disconnect and temporarily insulate one of the wires from the primary terminals of the high-voltage transformer.

DO NOT TOUCH ANY OVEN COMPONENTS OR WIRING DURING OVEN OPERATION. OBSERVE EXTREME CAUTION AND USE CLAMP-ON TYPE CONNECTORS DURING OPERATIONAL TESTING.

3. With a voltmeter set to measure up to 30 volts AC, connect the meter leads to the triac gate-input terminals. These terminals are identified as those which bear the smaller wires that come from the control panel. Figure 13–22 illustrates the proper meter connections for one common type of triac module: attach one meter lead to the terminal marked "blue" and the other lead to the triac terminal marked "green".
4. Apply power to the oven and bring the unit to an idle condition either by opening and closing the door or by switching the unit to "on", depending on the model. Do not, however, put the oven into a cook mode yet.
5. Observe the reading indicated on the meter.
   A. A reading of zero volts is normal. An abnormal voltage here indicates a defective gate-drive circuit in the control panel.
6. Put the oven into a full power cook cycle and note the reading on the meter.
   A. Normal gate voltages vary with different brands. However, readings within the approximate ranges of 1 to 6 volts AC, or 6 to 13 volts AC generally indicate that the control unit's triac-drive or gate-voltage circuit is operating normally. It should also be noted that some

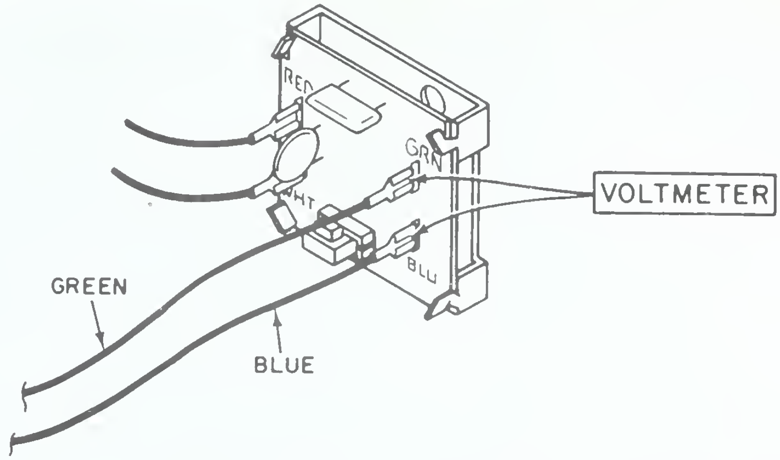


Figure 13-22 Triac module gate voltage verification. (Illustration taken from service literature copyrighted 1986 by Litton Microwave Cooking Products. Used by permission.)

models may have a normal delay of as much as 12 seconds before the gate voltage is applied. Abnormal results in the preceding test indicate a defective control unit, or a faulty connection.

13.16 AUXILIARY MODULE

Certain models of *Litton's Generation II* series use an *auxiliary module.* The auxiliary module consists of the triac, the low-voltage transformer, the oven relay, a pulse transformer, and additional supportive and protective circuitry. Other makes and models use similar components; for example, certain *General Electric, Hotpoint,* and *J.C. Penny* models use a "power control module" such as the one pictured in Figure 13-23. The power control module is comprised of circuitry similar to that of the auxiliary module. The following test provides some basic guidelines by

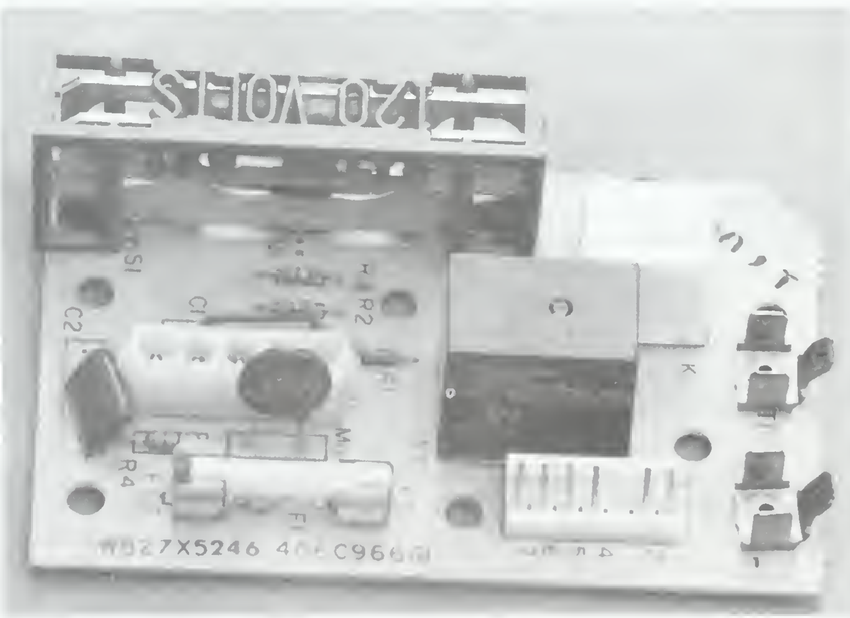


Figure 13-23 Common power control module.

which to test these types of circuits. It is recommended that miniature clip test leads be used. Also, in order to make good electrical contact, it may be necessary to scrape away or pierce a coating of varnish-type insulation that is coated on the module circuit board.

To present a general idea of how these modules are tested, the following test procedures are provided. Figure 13-24 illustrates the test points for an auxiliary module that is used in many of *Litton's* Generation II models. Before performing the tests, unplug the oven and DISCHARGE THE HIGH-VOLTAGE CAPACITOR. Then, disconnect either one of the leads from the primary terminals of the high-voltage transformer and temporarily insulate the connector to prevent an inadvertent electrical short. Test the auxiliary module components as follows:

> **CAUTION: OBSERVE APPROPRIATE SAFETY PRECAUTIONS DURING OPERATIONAL TESTING. DO NOT TOUCH ANY OVEN COMPONENTS OR WIRING DURING OVEN OPERATION. *ATTACH* METER LEADS WITH MINIATURE CLIP TEST LEADS WHEN CONDUCTING OPERATIONAL TESTS.**

> **WARNING: STATIC DISCHARGE CAN DAMAGE THIS ELECTRONIC ASSEMBLY. DO NOT TOUCH ANY PART OF THE ELECTRONIC CIRCUITRY UNLESS STATIC CONTROL MEASURES HAVE BEEN OBSERVED** (see *Section 8.6*).

Operational tests should be conducted in the following manner: First, unplug the oven and DISCHARGE THE HIGH-VOLTAGE CAPACITOR. Then, attach the voltmeter test leads to the appropriate test points. Finally, plug in the oven, close the oven door, and observe the meter for normal readings as indicated below.

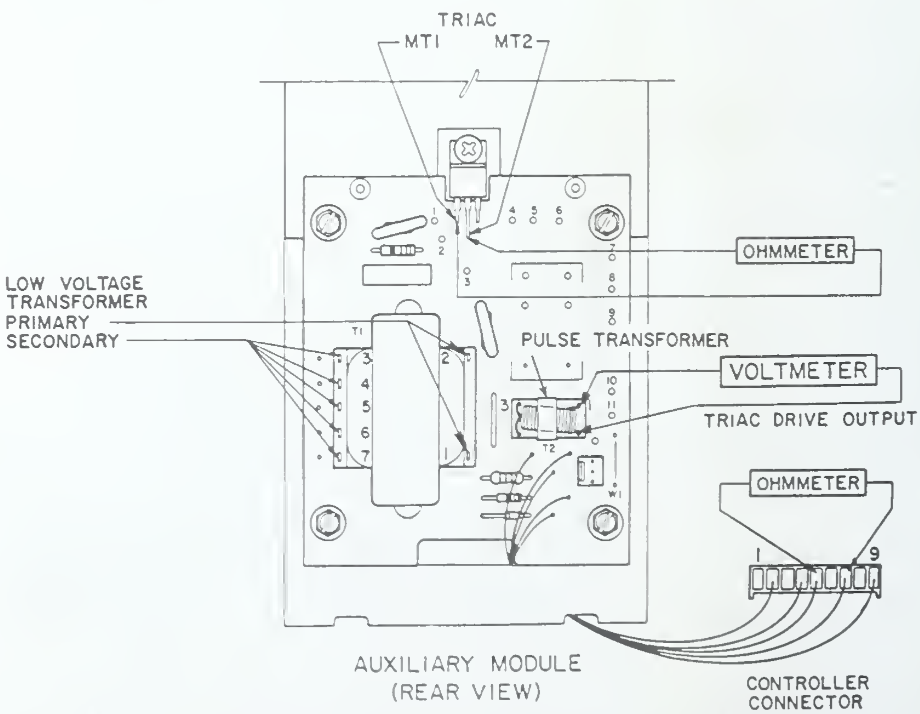


Figure 13-24 Auxiliary module test points. (Illustration taken from service literature copyrighted 1986 by Litton Microwave Cooking Products. Used by permission.)

Test Points	*Normal Reading*
1 to 2 (primary)	120 VAC
6 to 7 (secondary)	2.5 VAC
3 to 4 (secondary)	20 VAC (12 VAC some models)
4 to 5 (secondary)	20 VAC (12 VAC some models)

The oven relay, which holds the unit in the idle condition and provides a circuit to the blower motor, the cavity lamp, and one side of the high-voltage transformer primary input during the cook cycle, may be checked by measuring the resistance across its coil. WITH THE OVEN UNPLUGGED AND THE CAPACITOR DISCHARGED, connect an ohmmeter to pins #5 and #7 on the controller connector, and measure for a normal coil resistance of about 250 to 350 ohms.

The triac may be tested as follows: First, unplug the oven and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S). Using the miniature hook-type meter leads, connect the ohmmeter to the MT1 and MT2 terminals on the board-mounted triac. Set the meter to the R X 1 scale and measure for a normal indication of infinity (open). The triac's *gate-firing* capability can also be checked, as outlined in *Section 13.12.3.*

The triac-drive (or gate) voltage can be verified in the following procedure: 1) Unplug the oven, remove the cover and DISCHARGE THE HIGH-VOLTAGE CAPACITOR. 2) Disconnect one of the leads going to the primary winding of the high-voltage transformer so no high voltage will be generated during this test. 3) As shown in Figure 13-24, attach the miniature clip test leads to the *pulse transformer* output terminals. 4) Set the voltmeter to a scale capable of measuring 10 volts AC. 5) Apply power to the oven and initiate a full-power (high) cook cycle. 6) Observe the meter reading. A normal gate voltage of 0.7 to 3.5 volts AC during the cook cycle, and zero volts before and after the cook cycle, indicates that the triac-drive circuit is operating normally. With the cook control set to a medium power level, the meter should reflect a cyclic output. That is, about 6 seconds of "on" time (0.7 to 3.5 volts AC) and approximately 6 seconds of "off" time (zero volts AC).

The above voltages are conditioned on a LV transformer—primary input of 115 VAC. Otherwise, results substantially different than those noted above indicate a defective auxiliary module. For specific information regarding a particular model, the respective manufacturer's *current* servicing literature should be consulted.

13.17 SECONDARY-SIDE POWER-CONTROL COMPONENT CHECKS

Figure 13-25 shows, from left to right, the *high-voltage relay (Litton),* the variable *power switch (Panasonic*), and the *reed relay (Whirlpool*). These relays are all basically of the same type, serve the same purpose, and may be checked with an ohmmeter as follows:

1. Unplug the oven, remove the cover, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. Isolate the high-voltage relay from the circuit by disconnecting *all* leads that are attached to it.

3. Set the meter to the appropriate resistance scale and measure across the relay coil for a normal resistance of about 200 to 400 ohms (depending on the make).

4. With the leads still removed, set the ohmmeter to the highest resistance scale and measure between the following points, bearing in mind that any reading less than infinity (regardless of meter polarity) indicates a defective high-voltage relay: From one contact terminal (or wire) to the other; from each contact terminal to each

Figure 13-25 High-voltage switching devices.

coil terminal; from each contact terminal to chassis ground; from each coil terminal to chassis ground.

An operation check of the high-voltage relay is performed in the following manner:

1. Make certain that the relay is completely isolated from the "meter-eating" high-voltage circuitry by **DISCONNECTING ALL HIGH-VOLTAGE CONNECTIONS.**

2. A further precaution is to disconnect one or both of the primary leads from the high-voltage transformer (the disconnected leads should be insulated to avoid an inadvertent short). This will ENSURE THAT NO HIGH VOLTAGE IS GENERATED DURING THIS TEST.

3. During this test the two smaller leads that connect the relay coil to the control panel *remain connected.*

4. With the ohmmeter set on the R X 1 scale, attach one meter lead to each contact terminal (or wire—depending on the brand).

USE EXTREME CAUTION! *DO NOT* TOUCH COMPONENTS OR WIRING DURING OVEN OPERATION. USE CLAMP-ON TYPE CONNECTORS TO ATTACH THE METER PROBES.

5. Set the oven for a power level less than "high" and initiate a cook cycle.

6. Observe the meter while the oven is operating; the needle should cycle back and forth between continuity and infinity as the relay contacts close and open respectively.

If the contacts fail to operate, check for the appropriate DC drive voltage as follows:

1. Unplug the oven and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. With the [control] panel-to-coil leads remaining connected, attach a meter lead to each relay coil terminal, or lead. (NOTE: all other wires remain disconnected).

3. Set the meter to an appropriate DC scale and operate the oven again. Check for a relay-drive voltage of 15 to 29 volts DC (depending on the model). If the output power level is set to something less than 100 percent, the DC voltage should cycle between the proper drive (15 to 29) volts and zero volts.

13.18 CHECKING POWER RESISTORS

Visual checks are important here. Examine the resistor for cracking or burned areas. While the resistor may provide the correct ohmic value when cold, under use it may open, or increase in resistance. Any evidence of that nature should be taken into account. The resistance values are usually legibly imprinted on the body of the resistor or indicated on the oven schematic. The resistors may then be measured accordingly.

Associated control panel switching circuits should also be examined for insulation breakdown. This is evidenced by a burning smell during operation, as well as discoloration and brittleness of the terminals. The switch circuit may be checked by determining the appropriate terminals from the schematic and measuring the continuity in each switch position. A common symptom of a deteriorating power-selector switch is a failure to operate in one or more of the lower power modes.

13.19 TEMPERATURE CONTROL PROBE TESTING

Zero the ohmmeter on the R X 10,000 scale and place the ohmmeter leads on the probe plug as shown in Figure 13-26. One meter lead goes to the probe tip, and the other to the ground sleeve (meter polarity is not a factor). At room temperature the resistance should be approximately 30,000 to 75,000 ohms (depending on the brand). If either an infinite, or an extremely low resistance is indicated on the meter, replace the probe.

Leaving the meter leads attached, further test the probe by immersing its tip into a partially filled container of lukewarm water. Now take another container of very hot water and gradually pour its contents into the first container to achieve a gradual water temperature rise. The *increasing* ambient temperature of the probe tip in the hot water will be reflected (+/− about 10%) by a *decrease* in the probe's resistance. Place a thermometer in the water, along side the probe, and compare the rising water temperature to the approximate corresponding decreasing probe resistance. The following chart shows some typical probe resistance readings. Readings will vary with different models.

Probe Tip Temperature	*Approximate Probe Resistance*
77°F (25°C)	42,600 - 58,000 Ohms
90°F (32°C)	31,800 - 42,800 Ohms
100°F (38°C)	24,900 - 33,200 Ohms
150°F (66°C)	8,500 - 10,900 Ohms
200°F (93°C)	3,700 - 4,100 Ohms
208°F (98°C)	3,200 - 3,900 Ohms

13.20 SENSOR ELEMENT AND ASSOCIATED CIRCUITRY TEST

There are a number of different sensor cook systems used in the various makes and models. Rather than attempt to outline an appropriate test for each of them, a few very common procedures are offered to provide some general guidelines. Although

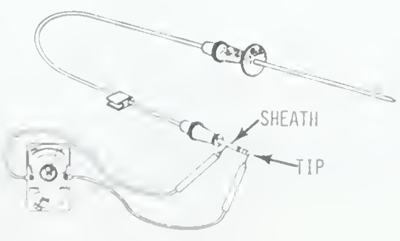


Figure 13-26 Temperature probe test. (Reprinted with the permission of White Consolidated Industries, Inc.)

the following procedure pertains to a popular line of *Panasonic* and *Quasar* models, the general methods and results may be adapted to suit many other humidity sensor systems. Figure 13-27 illustrates two types of humidity sensor units, each with their respective terminal designations.

TEST #1

1. Unplug the oven, remove the cover, and DISCHARGE THE CAPACITOR.

2. Locate the heater terminals (Fig. 13-27) and, using an ohmmeter zeroed on the lowest scale, measure across the heater for a normal "cold" resistance of about 6 ohms. If an abnormal reading is obtained, continue with the test, but watching closely in step #6 for the heater to glow red. A failure to glow combined with an abnormal resistance reading indicates a defective element.

3. Next, carefully unsolder the two wires connected to the sensor terminals, then, with an ohmmeter zeroed to its highest scale, measure across the sensor element. Since the value of the resistance is directly affected by the relative humidity, a normal reading is relative. The chart in Figure 13-28 presents a general idea of what to look for regarding the resistance of the sensor element.

4. The remainder of the test provides an operational check of the control circuitry. (The sensor terminal wires *remain* disconnected.)

NOTE: Static electricity can damage the sensitive control panel circuitry. Do not touch any part of the control circuitry. Discharge any static charge by grounding yourself to a grounded workbench or similar object.

5. Place a water load in the cavity and plug the oven in.

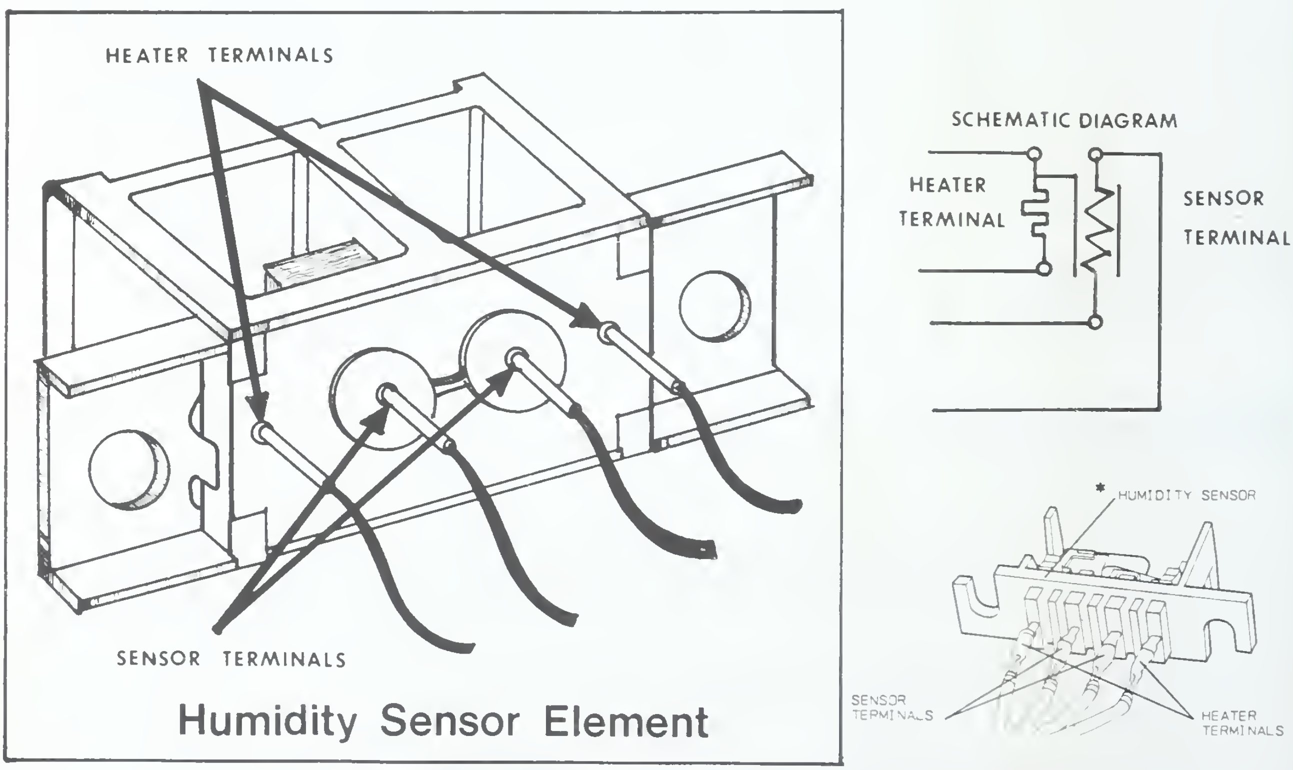


Figure 13-27 Humidity sensor terminal identification. (Courtesy of Michael S. Wagner and Matsushita Electric Corporation of America)

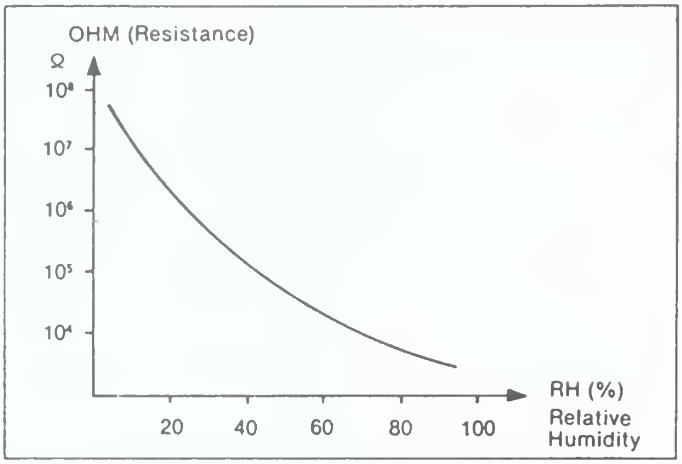


Figure 13-28 Sensor resistance in relation to humidity. (Used by the permission and courtesy of Matsushita Electric Corporation of America.)

6. Select a short-term sensor cook function on the control panel. In this case the control panel is set for auto sensor cook program "*A1*".

7. Press the start pad to begin the cook cycle. At this point the sensor heater should start to glow red.

8. After 10 seconds (from the time the start pad was pressed) connect the two previously unsoldered wires together for 5 seconds, then separate them.

9. After about another 45 seconds the oven lamp will dim slightly, indicating that the magnetron is pulling into oscillation.

10. 10 seconds after the magnetron starts oscillating, connect the same two wires together again. When the wires make contact, the auto cooking program should stop.

13.20.1 Results of Test #1

Results substantially different from those described indicate a defective control unit. If, on the other hand, the conditions described are obtained to a reasonable degree, it may be assumed that the control circuitry is functioning normally. Therefore, continuing problems in the sensor cook mode would likely be caused by a defective sensor element.

In *Sharp* models equipped with sensor cook the following procedure provides an effective self test of that circuit.

TEST #2

1. The oven must be plugged in for at least 5 minutes before an accurate test can be made.
2. Place a water load of 100 milliliters (about 3 ½ ounces) into the oven. The water should be at about room temperature (or about 68°F/20°C) and centered on the turntable tray.
3. Close the oven door and press the "sensor cook" pad, then select pad "2". The oven should go into the sensor cook mode and "*SC-2*" should appear on the display.
4. Press the "cook" (or "start") pad. The oven should operate for about 16 seconds before the magnetron is heard pulling into oscillation.

5. If the sensor is either *open,* or *shorted,* the word "*ERROR*" will appear in the display sometime after the initial 16 second cleaning cycle.
   A. If this should occur, check the wiring connections between the sensor and control panel. If the wiring is intact replace the sensor.
   B. It should be noted that a weak magnetron tube may also cause an "*ERROR*". If the sensor does not sense a humidity increase within a period of time the control panel will generate an "*ERROR*" signal. For example, if after 30 minutes the sensor has not detected the vapor of the food, "*ERROR*" will be displayed. BACON is the exception: if, when sensor cooking bacon, vapor is not detected within *1 ½* minutes, "*ERROR*" will be displayed. So, a weak magnetron may not produce enough cooking power to create the necessary humidity level within the specified time period, resulting in the "*ERROR*".
6. After approximately 1 to 2 ½ minutes (depending on the characteristics of the oven) from the time the "cook" pad was pressed the display should change from "*SC–2*" to a countdown of the remaining time.

13.22 INFRARED SENSOR

When symptoms such as; the oven cooks normally using time, but either overcooks or undercooks the food in the sensor mode (*Toshiba's* "Custom Select" feature), suspect a faulty *infrared sensor unit* or a poor connection between it and the control unit. An example of an infrared sensor check out procedure is as follows:

1. Unplug the oven, remove the cover, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. Remove the sensor unit connector from the control unit (Fig. 13-29) and orient the connector so its pin numbers 1 through 10 can be identified.

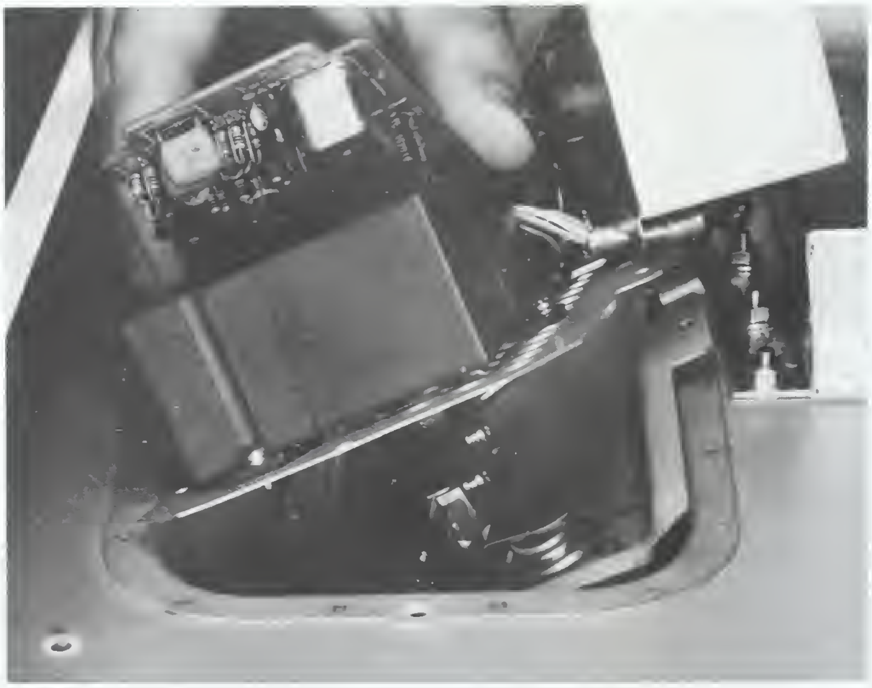


Figure 13-29 Remove the sensor unit.

3. Zero the ohmmeter on the R X 10 or next closest scale and measure from pin #3 to pin #4 (meter polarity is not a factor) for approximately 150 ohms at room temperature (68°F/20°C). This represents the coil resistance of the *vibrating chopper coil.*

4. Zero the ohmmeter on the R X 10,000 scale and measure from pin #9 (ground) to pin #6 (thermistor). This measurement reflects the thermistor's resistance relative to the ambient temperature, so the normal reading varies at a constant inverse ratio to the temperature of the thermistor, as shown:

Temperature	*Resistance (+/− 5%)*
50°F (10°C)	37,450 Ohms
68°F (20°C)	23,400 Ohms
77°F (25°C)	18,700 Ohms
86°F (30°C)	15,000 Ohms

If the resistance readings are significantly different than those shown, and symptoms exist such as those mentioned earlier, the infrared sensor should be replaced.

13.23 CONVECTION AND CONVENTIONAL COOKING CONTROL

In order to accurately check the temperature in a convection oven, or a conventional oven, a thermocouple-type temperature tester must be used. The thermocouple tip must be horizontally and vertically centered within the cooking cavity. The oven should be preheated to the desired testing temperature, then allow about 10 minutes (15 to 20 minutes for conventional ovens) for the cavity temperature to stabilize, after which the temperature measurement may be made. The actual temperature measured may differ to some extent from that which is displayed on the control panel, or set on the dial (whichever the case may be). In most cases, however, the overall cooking results will be satisfactory within that tolerance.

In addition, the time required for an oven to reach a desired temperature depends directly upon the voltage available to the oven. For example, if the household line voltage were 10 percent lower than normal, the cooking times may have to be extended by as much as 10 to 20 percent.

13.22.1 Heating Element Test

Insufficient heat circulation in the oven cavity may be caused by a defective heating element. After unplugging the oven, removing the outer cabinet, and DISCHARGING THE HIGH-VOLTAGE CAPACITOR(S), the element is checked by the following procedure. (This procedure applies to most convection units, as well as many models equipped with a simple browner element.)

1. Allow the element to cool completely.
2. Remove the harness leads from both ends of the element.
3. With the ohmmeter zeroed on the R X 1 scale measure across the element terminals for a normal reading of about 9.5 ohms.
   A. A reading of infinity means the element is open and should be replaced.

4. Set the ohmmeter on the highest resistance scale and measure from one terminal to the oven's metal chassis. The insulation resistance of the element should be more than 500,000 ohms.
5. A visual check can be made by observing the element's even red glow when voltage is applied.

13.22.2 Additional Notes on Convection Elements

In 1983 *Amana's* 1400 watt element for its RMC-20, RMC-20B, RMC-30, and similar CRMC models was judged to be of insufficient wattage for satisfactory browning, so a replacement 1550 watt element was made available.

Also, concerning *Sharp* models R-8310 and R-8314, there may be cases where the oven does not fully reach the temperature selected. In those cases, after verifying the problem by checking the temperature as outlined above, the temperature level may be raised in the following manner: Unplug the oven, remove the outer cover, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR. Identify the three variable resistors, VR-L, VR-H, VR100, located on the temperature control assembly. In order to keep the overall temperature control in balance, these variable resistors must be adjusted exactly as described and in the proper order.

1. First; adjust VR-L clockwise 1/16th of a turn.
2. Second; adjust VR-H counter-clockwise 1/16th of a turn.
3. Third; adjust VR100 clockwise 1/16th of a turn.
4. Re-check the cavity temperature as described above. If the temperature has not come up to the proper level, repeat the adjustment procedure until the proper cavity temperature is reached. Normally, one or two adjustments is sufficient.

13.24 THERMISTOR TEST

Two types of common thermistors that are used in many convection models are tested here. In each case the oven must be unplugged, the cover removed, and the HIGH-VOLTAGE CAPACITOR DISCHARGED.

THERMISTOR TYPE "A" (FIG. 13-30)

1. Disconnect the leads from the thermistor and remove the thermistor from the oven.
2. Visually examine the component side of the thermistor for severe corrosion of the thermistor leads. A cold thermistor unit may check good with an ohmmeter, but due to extreme corrosion, the thermistor lead will separate or short during actual operation.
   A. A defective thermistor will produce complaints such as; the cooling fan motor runs all the time, or comes on intermittently; the oven operates for 2 minutes then shuts off (check the damper motor and switch in a *Sharp* convection model that runs for one minute then shuts off); the oven will not cook in the convection mode; or the temperature of the oven cavity is lower or higher than preset.
3. Check the resistance of the thermistor as follows:
   A. Zero the ohmmeter on the R X 10,000 (or R X 10K) scale and, referring to Figure 13-30 for terminal location, measure from the "*COMMON*" terminal to the "*HIGH*" terminal (meter polarity is not a factor). The thermistor resistance should reflect the ambient temperature as shown:

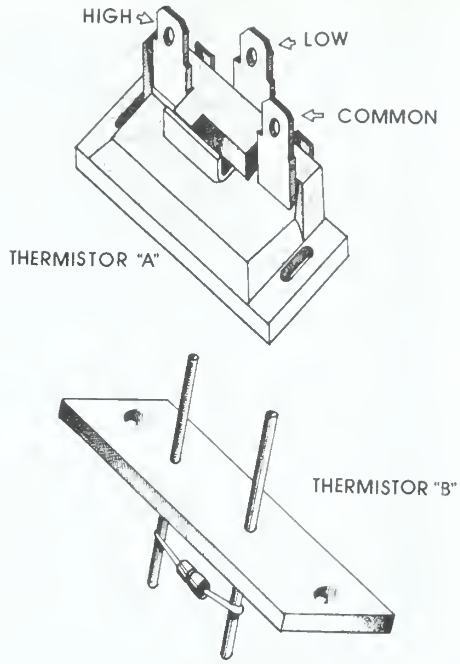


Figure 13-30 Thermistor terminal identification. (Courtesy of Michael S. Wagner)

Room Temperature	*Approximate Resistance in Ohms*
68°F (20°C) to 86°F (30°C)	322,000 to 165,000 respectively

B. Measuring from the *"COMMON"* terminal to the *"LOW"* terminal should produce the following readings:

Room Temperature	*Approximate Resistance in Ohms*
68°F (20°C) to 86°F (30°C)	68,000 to 35,000 respectively

C. Measuring from *"LOW" to "HIGH"* should read infinity.

THERMISTOR TYPE "B" (FIG. 13-30)

1. Disconnect one lead from the thermistor or remove its respective connector from the control unit.

2. Measure accross the thermistor terminals for the following resistances in relation to the room temperature:

Room Temperature	*Approximate Resistance in Ohms*
50°F (20°C) to 90°F (30°C)	800,000 to 155,000 respectively

If readings are obtained that are substantially different from these, the thermistor should be replaced and the oven re-tested for proper operation.

Safety and Protection Circuits: Tests and Failures

chapter 14

14.1 INTRODUCTION

Interlock and other type switches, as well as thermal protectors, thermal fuses, and fuses, can all be checked with an ohmmeter. In each test the oven should be unplugged and THE HIGH-VOLTAGE CAPACITOR(S) DISCHARGED. The ohmmeter should be set to the lowest scale (i.e., R X 1) since the readings will be either continuity (zero ohms) or infinity (no meter movement). In most cases the door interlock switches are activated by an arrangement of one or two latch hooks mounted on the door. The interlock switch to be tested in this example has a *COM.* (common) terminal, a *N.O.* (normally open) terminal, and a *N.C.* (normally closed) terminal.

14.2 DOOR INTERLOCK SWITCH TEST

1. Unplug the oven, remove the outer case, and discharge the capacitor by shorting its terminals together and to ground with the blade of an insulated screwdriver.
2. Visually examine the switch, the terminals, and the connectors for discoloration or brittleness due to overheating. Primary causes of overheated connections are loose slip-on connectors and poor crimp joints. In addition to that, many times the plastic insulators that encase the connectors will actually trap heat, aggravating the problem. If this is happening, first make sure that the slip-on connector is not loose and is properly crimped. Then, if the insulator can be removed without creating the danger of a short, remove and discard the plastic insulator.
3. Carefully remove the harness leads from the switch terminals. (Note: this test can be made without removing the harness leads, or by just disconnecting the *COM* lead. However, due to parallel circuits that may exist,

readings that would have indicated infinity will, instead, show the resistance of the parallel circuits.) When connectors do not readily slip off, do not exert too much force or the terminal may break right out of the switch. Many times the connector can be gently pried off by placing the tip of a flat-bladed screwdriver between the switch body and the front edge of the slip-on connector; then, while jiggling the connector with one hand, slowly pry the connector off with a twisting action of the screwdriver blade. If the connector does not jiggle off easily, it may be a locking-type connector. Many manufacturers are using a connector with a locking clip in the center of the receptacle terminal. To remove this type of connector, press down on the extruding lever (locking clip) while gently pulling the connector off of the terminal.

4. As demonstrated in Figure 14-1, place one meter probe on the *COM.* terminal and the other probe on the *N.O.* terminal (terminal locations are indicated on the switch casing). With the actuator (or lever) not depressed, which in most models is the effect of opening the oven door, the meter should read infinity (or an open circuit).
5. With the meter remaining connected as in step 4, press down on the switch actuator until an audible"click" is heard. In most models this is the effect of closing the oven door. At the point of the "click" the meter should swing to a reading of zero ohms (or continuity).
   A. As a rule, a healthy audible "click" usually means the switch is working normally.
6. Move the one meter probe from the *N.O.* terminal to the *N.C.* terminal as shown in Figure 14-1. (The other probe remains on the *COM* terminal.) With the actuator not depressed the meter should read zero ohms (or continuity).
7. Actuating the switch should produce a reading of infinity.
8. Set the meter to the highest resistance scale and measure from the N.C. terminal to the *N.O.* terminal. A normal reading of infinity should be indicated on the meter.
9. With the meter remaining on the highest scale, measure from each terminal to any metal mounting rivets or studs that may be a part of the assembly. A normal reading of infinity should be observed here also.
   A. A switch that is sparking (during opening or closing) to the extent that it intermittently arcs-over to its chassis mounting studs, bracket, or plate, can be the source of an aggravating fuse blowing problem.

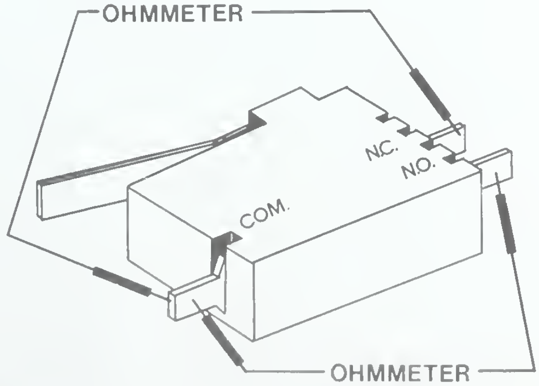


Figure 14-1 How to check a switch. (Courtesy of Michael S. Wagner)

Each momentary high-resistance short gradually weakens the fuse, so that it eventually opens during a cook cycle. This creates a very misleading symptom, since it tends to draw suspicion away from the real source of the problem, the sparking door switch.

This menacing malfunction is usually caused when a hairline crack, virtually invisible, forms in the insulator of one of the interlock switches. Current flow through, and voltage potential across, the switch combine to build a carbon track to chassis ground. In time, through current leakage, the track builds to the point where it occasionally arcs over to ground. The arc can be detected by observing the switches (in a darkened room if necessary) while opening and closing the door during a full power cook cycle. Watch for extreme internal arcing, sparks dancing along the terminal, or streaks of sparks leaping toward the metal mounting stud. If applicable for the model under test, close the oven door and watch for the same. Also, removing and examining the switch and its mounting may reveal carbon tracks—the evidence of intermittent arcing. If severe arcing, sparking, carbon tracks, or cracks are observed the switch should be replaced.

Due to different applications, some switches (such as interlock-monitor switches) are constructed with only the *COM.* and *N.C.* terminals. These should be checked as in steps #6 and #7 of the preceding test. Other switches are made with just *COM.* and *N.O.* terminals, which are checked as outlined in steps #4 and #5. All switches, regardless of their application, may be checked as described in step #9.

14.3 INTERLOCK SWITCH ADJUSTMENT

While the following guidelines apply in particular to the installation and adjustment of door interlock switches, they also pertain generally to the adjustment of most other snap-action type switches. They are: 1) Ideally, a door interlock switch should be adjusted so the door hook or lever is vertically and horizontally centered on the switch actuator as they meet. 2) The switch should be adjusted so that, on a horizontal plane, the door hook is not allowed to travel past the switch button if the door is slammed. 3) When the door is completely closed the switch actuator should be depressed to a point just beyond the point where the actuating "click" is heard, but not so far that the switch actuator arm makes forceful contact with the switch body. When making this adjustment it is usually not necessary to bend the switch arm; rather, make any adjustment by means of the appropriate adjusting screws. 4) When the door is opened, the actuator arm should be allowed to travel just beyond the point of the actuating "click" before meeting any sort of stop. 5) The proper interlock sequence can normally be verified by ear in lieu of ohmmeter testing: when the door is opened the first "click" is the latch or primary interlock switch opening; the next "click" is the secondary interlock (or *Amana's* "left interlock") opening; and finally, the third "click" is that of the interlock monitor switch closing.

Do not attempt to repair sticking contacts of any interlock safety switch. Any indication of switch malfunction during testing requires replacement of that switch to insure the reliability of the monitoring and safety interlock system.

If at any time the oven fuse blows due to a fault in the interlock system, it is strongly recommended—and required by many manufacturers—that all switches associated with the monitoring system be replaced at that time. This is because the current surge that blew the fuse will almost certainly have damaged the contacts of these important switches. It is important that the switches be replaced with the exact

same type in order to meet strict Federal requirements. Defective or questionable switches should be destroyed to prevent possible future inadvertent use.

Adjust an *interlock switch latch strike assembly* as follows: Unplug the oven and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S). Slightly loosen the switch assembly mounting screws so that the assembly will move, but with limited freeness so it will hold its position. Close the oven door and, while pressing lightly inward on the door, allow the switch assembly to comfortably align itself to the door hook as shown in Figure 14-2. As a final adjustment, align the switch assembly to provide the maximum activation of the interlock switch. The strike assembly should be adjusted so that the door hook does not travel *past* the switch actuator (or button). And, by the same token, the door should not have to be slammed or bumped to get the switch assembly to engage the door hook. When satisfactory adjustment is achieved, re-tighten the mounting screws. Latch assemblies such as these are most successful when the door is gently closed with the hand vertically centered between the upper and lower door hooks.

To adjust a *switch module,* a little more finesse is required because the audible reference of the "click" is absent. Refer to the illustration of a typical switch module in Figure 14-3. First, slightly loosen the switch module mounting screws so that the module will move, but with some resistance. Close, and lightly press inward on the oven door, and allow the module to pull itself on to the door hook. Align the switch module so as to provide maximum activation of the switch actuator, while maintaining a minimum amount of play between the door and the oven facing. Re-tighten the mounting screws.

Anytime a door interlock switch is replaced, adjusted, or when associated repairs are made, a RF leakage check must be performed to insure compliance with the guidelines established by the U.S. Government Department of Health and Human Services (21CFR Part 1030). The RF leakage survey, the procedure of which is outlined in *Section 15.7.1,* should be conducted using an industry-approved RF meter that is properly calibrated (refer to *Section 5.2.3* for a list of approved

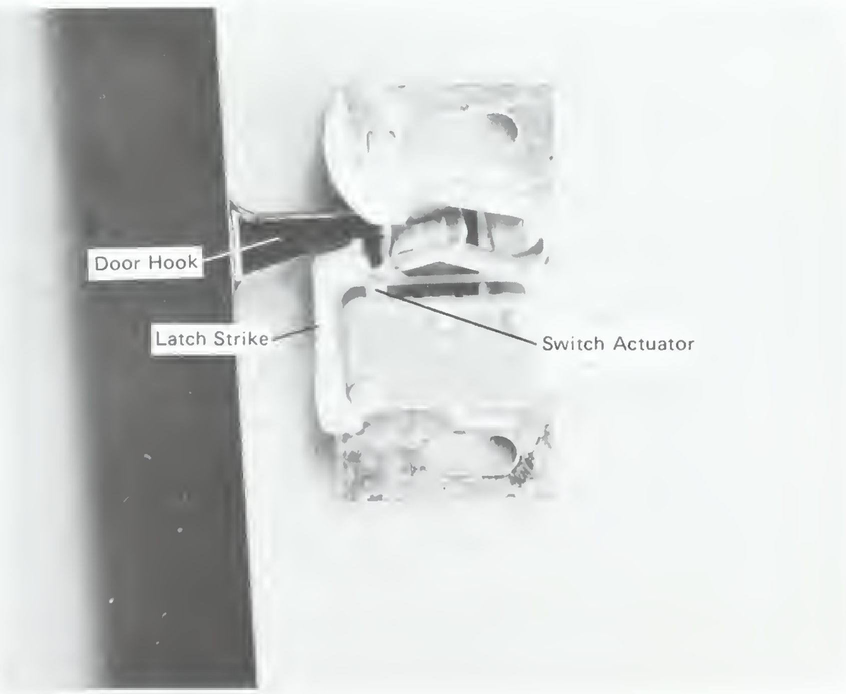


Figure 14-2 Interlock switch latch strike assembly.

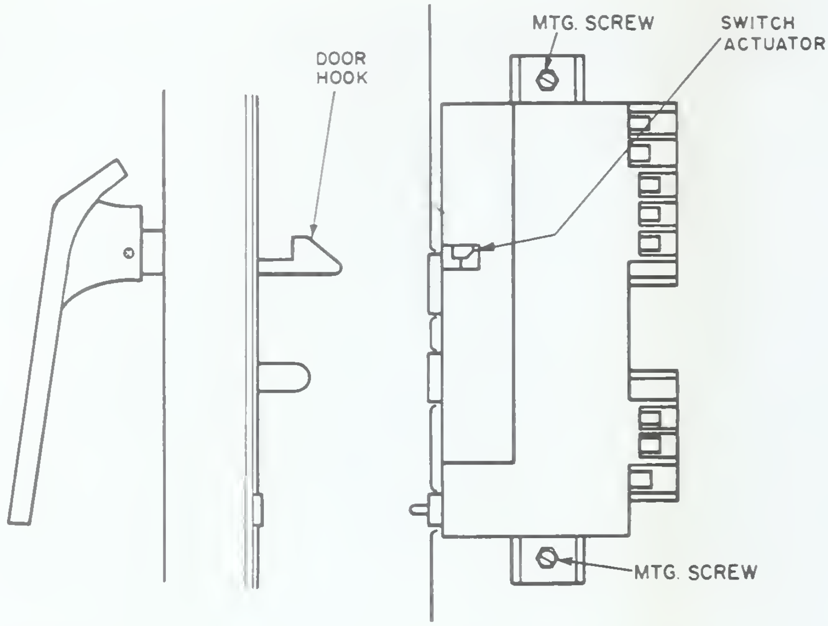


Figure 14-3 Adjusting a switch module. (Illustration taken from service literature copyrighted 1987 by Litton Microwave Cooking Products. Used by permission.)

instruments). The maximum leakage level allowed by the DHHS and the microwave oven industry is 1.0 MW/CM^2 (milliwatts per square centimeter) at the factory (prior to acquisition by a purchaser) and 5.0 MW/CM^2 after the sale, on location, over the life of the oven.

14.4 AMANA LATCH SOLENOID

In conjunction with the latch interlock, most older domestic *Amana*-made ovens use a latch solenoid such as the one pictured in Figure 14-4. This solenoid is an electrically operated device that keeps the door from being opened while the unit is in operation. The solenoid coil can be checked with an ohmmeter as follows:

1. Unplug the oven, remove the cover, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).
2. Carefully disconnect one of the leads from the latch solenoid assembly.
3. Zero the ohmmeter to the lowest ohms scale and measure across the solenoid terminals for a normal resistance of approximately 450 to 500 ohms (this value may vary).
   A. An infinite reading indicates that the coil is open and the solenoid must be replaced.
4. A second method to test the solenoid is to remove both harness leads from the solenoid terminals and in their place connect a 115 volt test cord. Plug in the test cord and observe the operation of the latch solenoid assembly.

If the solenoid assembly must be removed or adjusted, be sure to properly insert the plunger shaft engagement pin into the linkage assembly when reassembling the unit. Check the plunger shaft by manually pressing it into the solenoid, then releasing it. Be sure it moves freely in both directions.

An improperly adjusted or installed latch solenoid assembly can create the

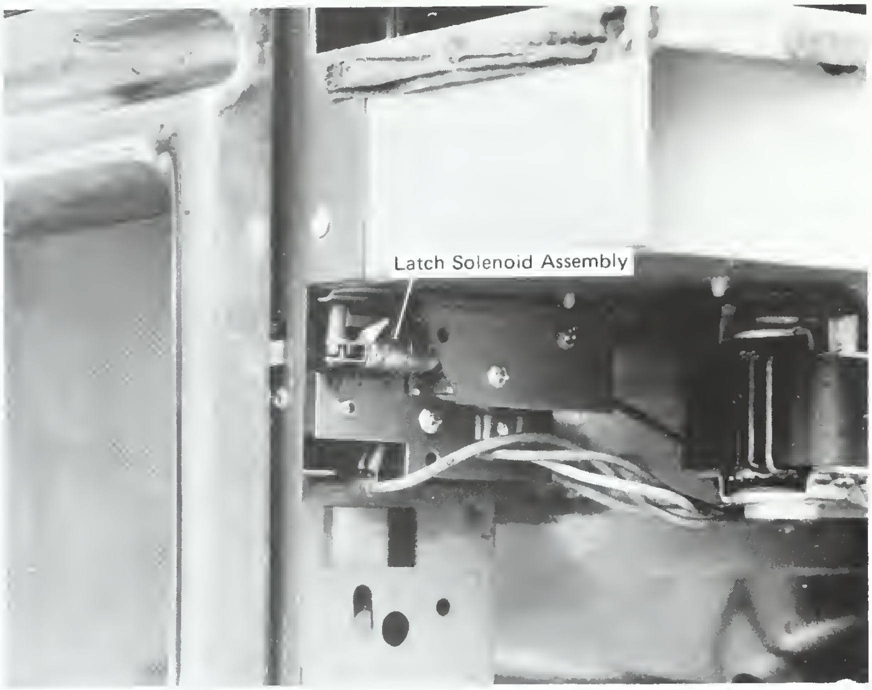


Figure 14-4 Amana latch solenoid.

following symptoms: a loud mechanical buzz for the first few minutes, or longer, of a cook operation; and, at the completion of the cook cycle, it can bind and prevent the door from being opened.

14.5 AMANA MULTIPROTECTOR ASSEMBLY (FIG. 14-5)

Both the thermal fuse and fuse resistor of this assembly can be checked with an ohmmeter as follows:

1. Unplug the oven, remove the outer case, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).
2. Identify the fuse leads, as opposed to the leads of the tube resistor, and measure across the fuse for continuity. With the meter on the lowest scale, a normal reading of less than 1 ohm (continuity) indicates an intact fuse. A reading of infinity means the fuse is open, in which case the source of the problem must be corrected before the fuse is replaced. If the transformer protect fuse has opened, look for a problem in the high-voltage section. If the interlock-protect fuse has opened, look for a misadjusted or defective interlock switch.
   A. If, after several minutes operation, for no apparent reason, the transformer protect tube resistor gradually gets very hot, then eventually the transformer-protect fuse opens and the oven becomes inoperative, the high-voltage transformer probably has a shorted winding. A shorted diode, capacitor, filament transformer, or magnetron will also open the transformer-protect fuse. In those cases, however, the symptoms are more obvious and immediate.
   B. *Amana*-made models with counterbalance arms, such as is shown in Figure 14-6, tend to have a wear-related problem in that the counter-balance arm wears a flat spot on the counter-balance arm roller. This

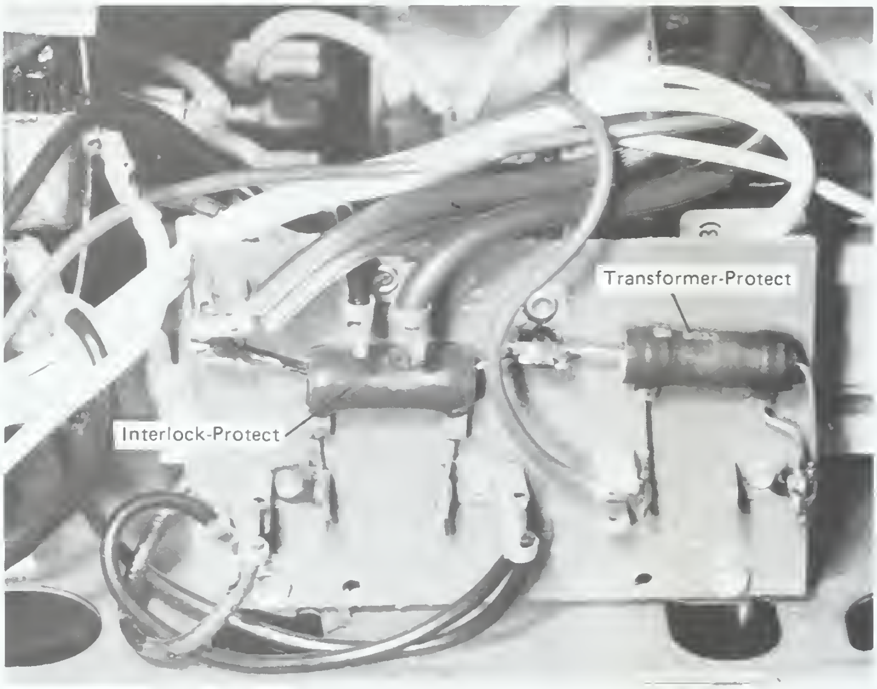


Figure 14-5 Multiprotector assembly.

puts the interlock sequence out of order and eventually causes the interlock-protect fuse to open.

C. If, on this type of *Amana*-made model, the right-hand door spring breaks, the *sensing switch* (monitor switch) will not be properly actuated when the door is closed. Thus the sensing switch remains in the closed position, thereby causing the interlock-protect fuse to open when the door closes.

Figure 14-6 Counterbalance arm assembly.

(1) When either door spring breaks, it usually does so with an alarming "pop!" as the door is either being opened or closed.

3. Before testing the tube resistor, isolate one side by removing the harness lead. Then measure across its terminals for the appropriate resistance, the ohmic value of which is usually indicated on the body of the resistor. (An exception is the glass-type tube resistor. Typical resistances range from 95 to 155 ohms; however, the appropriate service literature should be consulted for final verification.)

14.5.1 Replacement of Thermal Fuses

The performance of a thermal fuse can be adversely affected by improper installation. Certain precautions regarding soldering techniques and the forming of the leads must be taken to ensure against premature nuisance failures. The guidelines offered here apply generally to all replacement procedures that involve the soldering of sensitive and delicate devices.

The leads of the thermal fuse must be heat-sinked to prevent the solder heat from damaging the fuse link. This is accomplished by attaching a heat-sinking device (or, an alligator clip, a paper clip, a pair of needle nose pliers) between the soldering point and the fuse body as shown in Figure 14–7. The heatsink diverts and absorbs the heat so that the heat-sensitive fuse is not affected when the leads are soldered. Before soldering, insure that the surfaces to be soldered are clean and the tip of the soldering iron is adequately tinned (a clean thin coating of solder) so the connection can be made quickly. Solder as far as possible from the fuse body. Do not use an acid-core solder or a non-core solder with the can-type acid-based flux. Acid-based flux is for plumbing use only and will result in a poor connection and cause eventual corrosion and deterioration of the part. Use a good quality rosin-core electronic solder and a soldering iron capable of applying enough heat for a good solder flow, otherwise a cold solder joint may result. Do not use an iron that is too large, and do not prolong the application of heat to the joint (a maximum of 10

Figure 14–7 Use a heat-sinking device when soldering a thermal fuse.

seconds at a time), otherwise the fuse may be damaged. Insure that the fuse is centered within the resistor. Dress the fuse leads so that they do not come in contact with, and are centered within, the rims of the tube resistor. Special care must be exercised when configuring the leads to insure that the end seal is not cracked or otherwise damaged. Use needle nose pliers to support the lead near the fuse body before bending the lead.

Do not substitute fuses unless the trip temperatures are within an acceptable range of each other. Usually the trip temperature of the fuse is indicated on the fuse body in either degrees fahrenheit or degrees centigrade (celsius). As a general rule, when replacing a thermal fuse with a trip temperature less than 120°C (248°F), the replacement fuse should have a trip temperature within 4°C (7°F) of the original fuse. If the original fuse has a trip temperature greater than 120°C, the replacement fuse should be within 8°C (14°F) of the original fuse.

14.6 CHECKING THERMAL PROTECTORS—RESETTABLE AND NON-RESETTABLE

When the thermal protector (thermal cut off, or non-resetting thermal fuse) is suspected, an initial visual check should be made. Look for evidence of overheated, corroded, or burned terminals. If the device appears normal visually, it may be checked with an ohmmeter as follows:

1. Unplug the oven, remove the outer case, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).
2. Carefully remove the harness leads from at least one terminal using the same precautions as outlined in step #3 of *Section 14.2.*
3. Zero the ohmmeter on the lowest (R X 1) scale and measure across the terminals of the thermal protector.
   - A. Unless an overheating condition has occurred, the *N.C.* (normally closed) type of thermal protector should show continuity (zero ohms) across its terminals, showing that its contacts are closed. If an overheating condition has tripped the resettable thermal type of protector, it should indicate infinity across its terminals (showing that its contacts are open) until it cools sufficiently to automatically reset.
   - B. The non-resettable thermal *fuse,* once having reached its trip point, will show infinity across its terminals and must be replaced.
   - C. The *N.O.* (normally open) type of thermal switch should indicate a reading of infinity across its contacts under normal conditions. If an overheating condition exists, the *N.O.* thermal switch should give a reading of continuity (or a closed circuit) until the condition abates.

14.6.1 Common Causes of Thermal Protector-Related Failures

1. Loose terminals or terminal connectors will eventually overheat and burn loose, as was the case with the thermal protector in Figure 14-8.
2. Insufficient air flow, either to or from the blower.
   - A. Blocked intake or exhaust vents.
   - B. Failing or stalled blower motor, which may be as a result of worn bearings or an open winding. Replace the motor.

Figure 14-8 Thermal protector burned due to a faulty terminal connection.

C. A blower wheel or blade that is loose on the motor shaft (see *Section 16.2, item 5* for a corrective procedure).

D. The blower wheel or blade is in a bind, either with the scroll or ducting.

3. Depending on the model, either the air ducting or other enclosure is out of its proper position, or the air baffle (or gasket) material has deteriorated and lost its effect.

A. It is not uncommon, in some *Amana*-made domestic models, to find that the white plastic magnetron cover is not properly locked in place, as shown in Figure 14-9. As a consequence, much of the air is allowed to escape instead of flowing through the cooling fins of the magnetron, thus an overheated condition results. Also, as in the following conditions, the air-driven stirrer blade (or antenna—de-

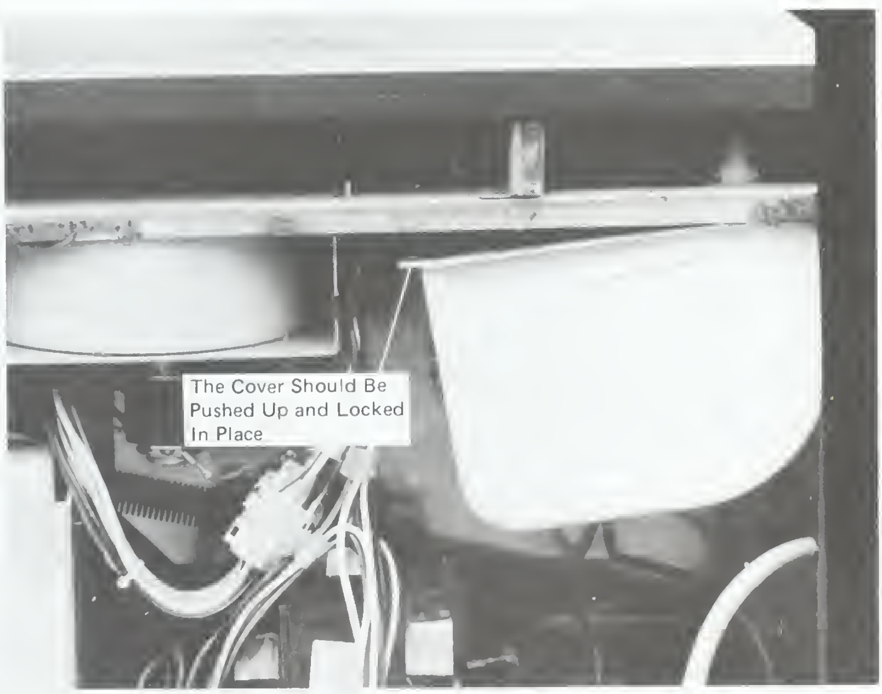


Figure 14-9 Loose magnetron cover.

pending on the model) will cease to rotate. However, later production models have an added retaining screw that keeps the cover securely in place, thus alleviating the problem.

B. Another common wear-related failure occurs in *Amana*-made domestic models when the air-driven antenna, or stirrer blade (depending on the model), stops rotating. In addition to the obvious uneven heating, the non-rotating antenna (or stirrer blade) can also create reflected energy which eventually causes the antenna assembly to melt and burn (Fig. 14–10), the magnetron tube to overheat and, consequently, the magnetron *thermal fuse* to open. Other than a defective blower motor, this is usually caused by one or both of the following: 1) Over a period of time the center of the grease shield begins to sag. This either interferes with the air-driven stirrer blade, or, in the case of a rotating antenna, diminishes the air swirling action which is required to rotate the antenna. 2) The foam gasket material that channels the air into the antenna (or stirrer blade) compartment deteriorates and allows air to escape. In Figure 14–11 a deteriorated air-flow gasket is being replaced with new foam gasket material.

4. Popping successive bags of microwave popcorn over a prolonged period of time will cause many units to overheat.

14.7 FERRITE ISOLATOR TEST

The isolator, which is used on most commercial *Amana* ovens, is checked visually. Remove the grease shield and, using a flashlight, look up into the waveguide opening. The isolator should be visible. Examine the interior of the waveguide for any irregularities such as melted ferrite disks or evidence of arcing and burning. The failure of an isolator is usually accompanied by a pungent odor and smoke.

Figure 14-10 Burned antenna assembly.

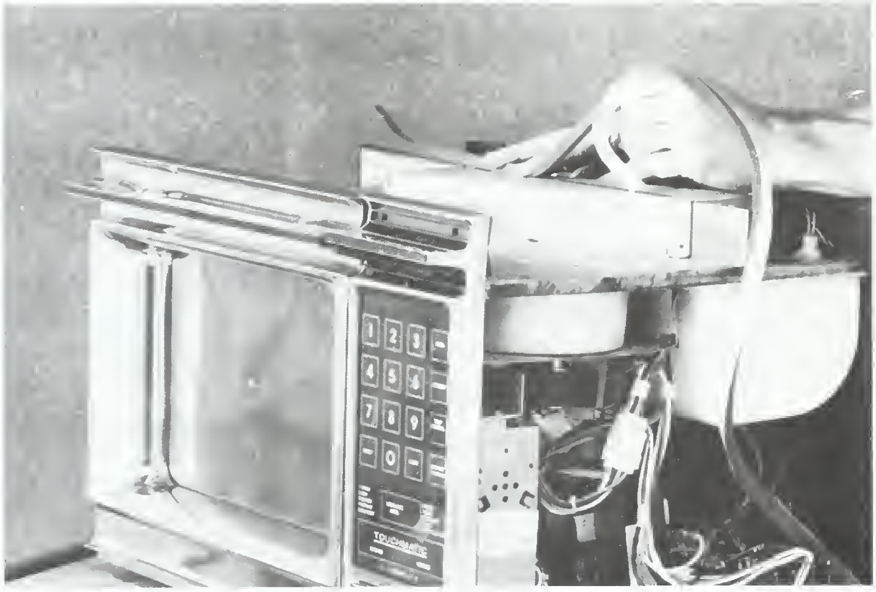


Figure 14-11 Replacing an air-flow gasket.

The isolator thermal protectors are checked in the same manner as previously outlined for other thermal protectors. Keep in mind that one thermal protector (usually at the rear) is *normally closed,* and the other one (usually at the front) is *normally open.*

14.7.1 Isolator removal and Replacement Considerations

CAUTION: ENSURE THAT THE OVEN IS DISCONNECTED FROM THE POWER SOURCE AND THAT THE HIGH-VOLTAGE CAPACITORS AND THE BY-PASS (RF) CAPACITORS ARE DISCHARGED BEFORE REMOVING OR REPLACING ANY COMPONENTS.

Remove the isolator as follows: 1) Remove the rubber isolation pads (do not discard these, as they will be re-used), and drill out or cut off the pop rivets. 2) Remove the thermal protectors. 3) Remove the mounting screws, including the screw that secures the isolator to the cavity ceiling. This usually gold-colored screw can be accessed by removing the grease shield and locating the screw in the cavity ceiling. 4) Remove the isolator.

NOTE: Never operate the oven without the isolator properly secured in place.

Replace the isolator as follows: 1) Ensure that all metal shavings and remnants of pop rivets are removed. 2) A new gasket and special pop rivets which should be supplied with the replacement isolator must be used in the installation. 3) It is IMPORTANT that the ARROW on the isolator points toward the magnetron tube. 4) Line up the new gaskets flush with the edge of the isolator, then seat the isolator into the waveguide. 5) Insert and hand tighten all of the mounting screws. 6) With the isolator properly seated and the rivet mounting holes aligned, begin by tightening the screw that secures the isolator to the cavity ceiling. Then tighten the remaining screws. 7) Install the special pop rivets and reinstall the rubber pads. 8) When the installation is complete, the isolator and associated repair areas must be checked with an approved RF leakage tester to make sure that the repair did not create a radiation safety hazard, and to ensure compliance with the federal guidelines for microwave leakage.

14.8 SURGE MONITOR SYSTEM

Certain commercial *Amana* ovens (i.e., RC14B, second-generation RC14S) use a *100 millisecond delay board* in conjunction with a *surge relay* to monitor the action of the unit's *power relay*. Figure 14–12 shows the surge monitor components in a typical commercial model. If the contacts of the power relay ever fail to open at the completion of a cook cycle, the following protective sequence occurs: Refer to Figure 14–13. At the end of a cook cycle the timer deactivates the control relay. The control relay's contacts open, which in turn, opens the circuit to the power relay and the surge relay. The surge relay contacts open, putting the 10 ohm 20 watt surge resistor between the welded-closed power relay contacts and the primary winding of the power transformer. The resulting current flow through the resistor, as indicated by the solid arrows, causes it to quickly overheat and open. The open surge resistor, serving as a fuse, opens the circuit to the transformer, and thus the high voltage section becomes inoperative.

When this type of failure occurs, the power relay and the surge resistor must be replaced. However, the surge relay and the time-delay board should also be checked for proper operation. Refer to *Sections 13.7.3* and *13.7.2,* respectively, for those test procedures.

14.9 CHECKING VOLTAGE PROTECTION DEVICES

Varistors, snubbers, filters, and surge absorbers (suppressors) are designed to protect electronic circuits, and generally do not cause any problems unless they have arrested, shunted, or absorbed a voltage spike or surge of an amplitude beyond their

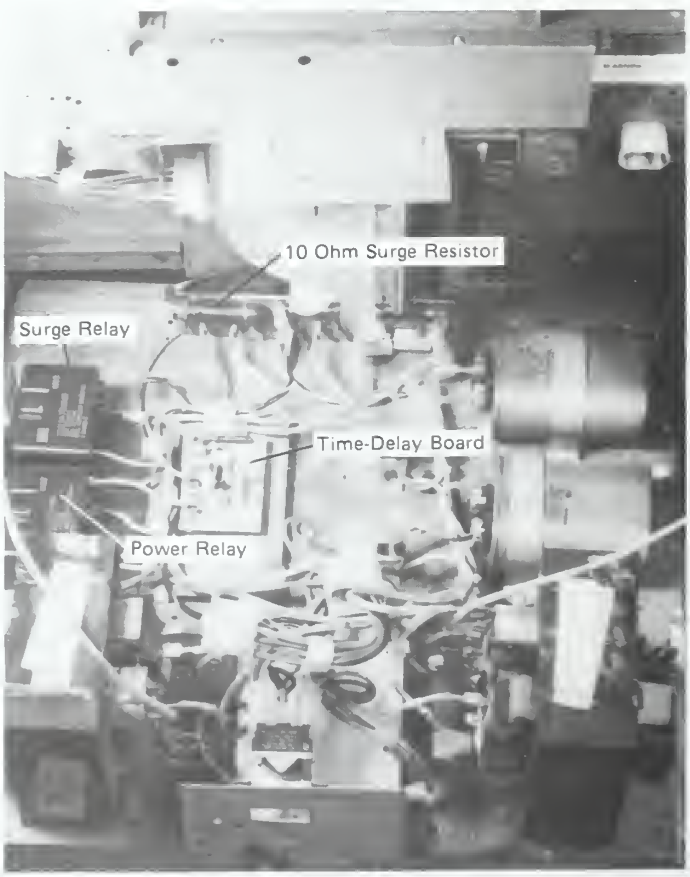


Figure 14–12 Surge monitor components.

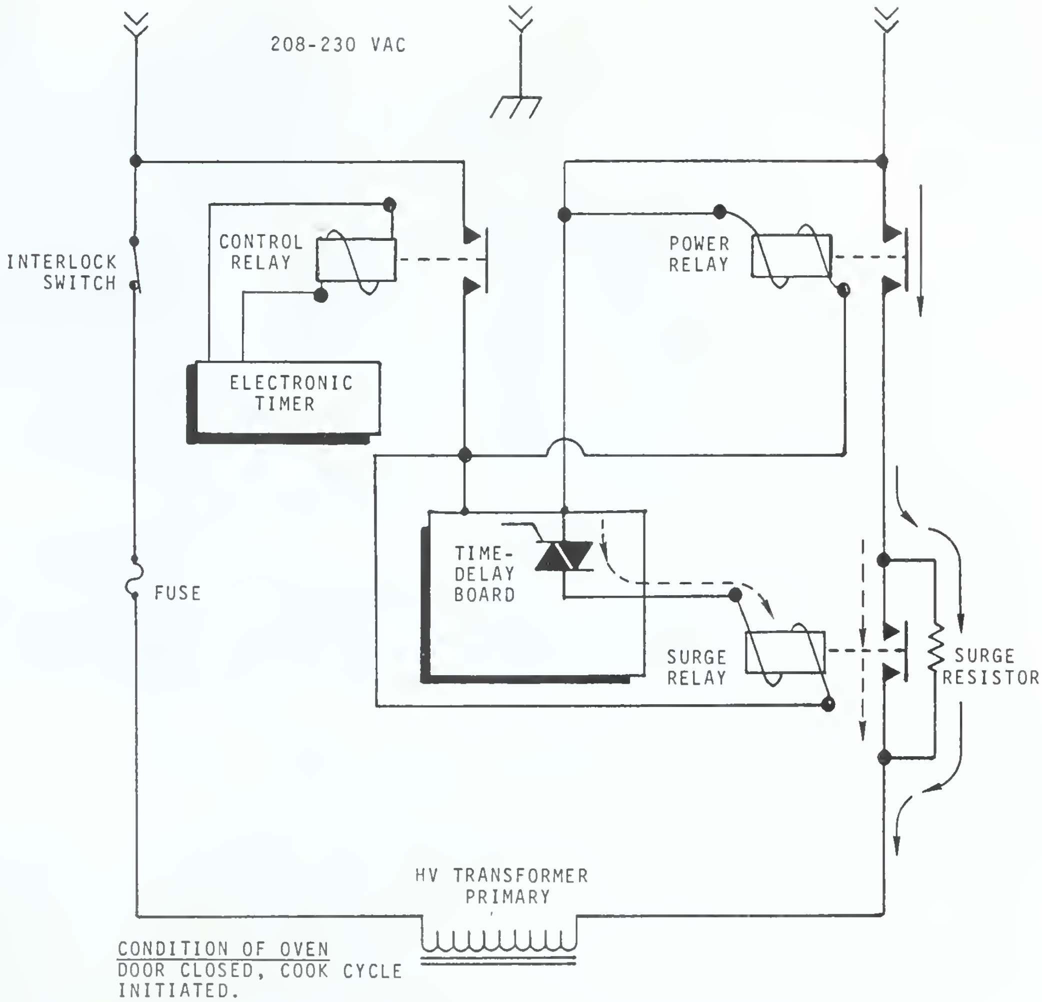


Figure 14-13 Surge monitor circuit operation.

threshold; in which case a visual inspection will generally suffice. For example, the varistor (or what is left of it) in Figure 14-14 created a short circuit across its terminals when hit by a surge—probably from a lightning strike. Clearly, the voltage surge exceeded this varistor's breakdown threshold, so the varistor caused a self-sacrificing short-circuit which immediately blew the line fuse. If another fuse is installed without replacing the shorted varistor, the new fuse will simply blow again—usually accompanied by a few sparks from the remnants of the varistor. After removing the shorted varistor an interim operational check will reveal any further damage. Then, when appropriate, a new varistor can be installed. Sometimes the varistor is virtually disintegrated during the surge, so, even though replacing the fuse may restore the oven back to operation, the varistor must also be replaced. In other instances a shorted varistor may be cracked, split apart, or merely have a burned appearance. A normal ohmmeter reading across an intact varistor is near-infinity.

CAUTION: Static discharge can damage static sensitive control circuitry. Handle the circuit board by its edges only; or ensure that the soldering iron, work bench, and technician are properly grounded (see *Section 8.6, item 1*).

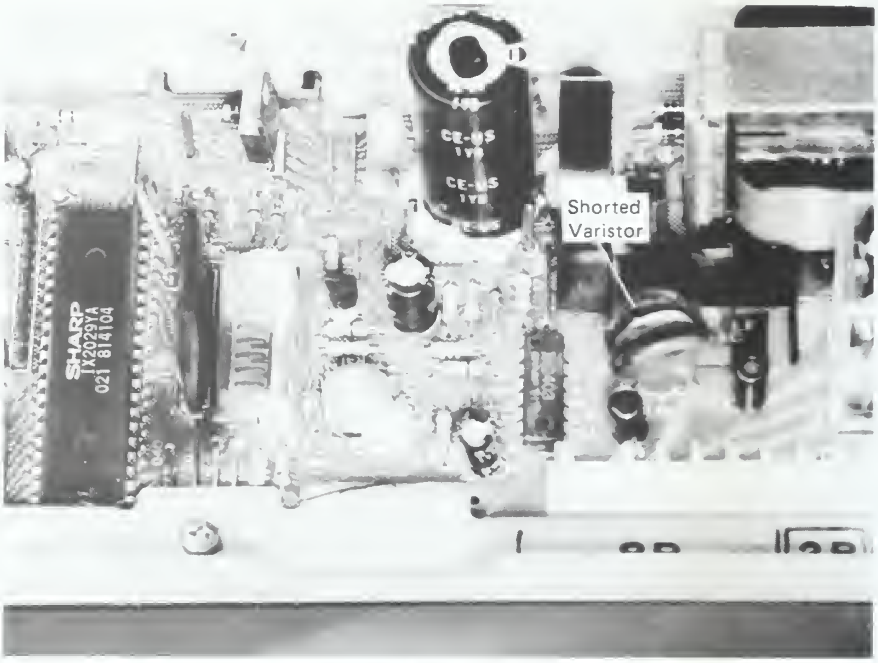


Figure 14-14 Shorted varistor.

14.9.1 Foil Patterns and Filter Coils

Other protective arrangements that are repairable are the fine *foil patterns,* or the *filter coils* (depending on the model) that *Sharp* and some others provide on their circuit boards. These act to fuse the primary side of the low-voltage transformer, which is mounted directly on the printed circuit board. If the foil pattern or filter coil is open, visually inspect the varistor for damage and replace the varistor if necessary. Also, check the primary coil resistance of the low-voltage transformer (typical resistance is approximately 250 to 300 ohms). If the transformer coil is open, the entire circuit board may have to be replaced, depending on the availability of a replacement transformer. If everything checks normal, the foil patterns can be restored. Figure 14-15 is a typical foil configuration. The procedure is as follows: If the foil is open at point "A", solder in a jumper wire from point "B" to "C". If the foil pattern is open at point "A" and from "B" to "C", solder in a 22 microhenry filter coil (*Sharp* part # RCILF2003YAZZ) between points "D" and "E". If, instead of the foil patterns, the board was originally equipped with one or two filter coils, they can be checked for continuity with an ohmmeter. An open coil can be replaced with the same 22 microhenry coil mentioned above.

14.9.2 PTC Surge Resistor Test

Unplug the oven, remove the side panel, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR. With the ohmmeter zeroed on the lowest scale, measure this

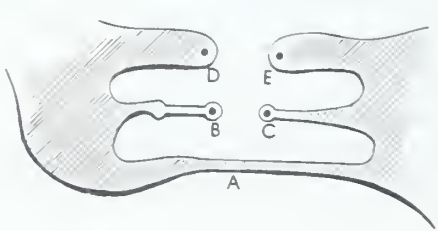


Figure 14-15 Repairable foil patterns serve to fuse the circuit board.

unique type of surge resistor for a normal reading of about 10 ohms at room temperature. If the Positive Temperature Coefficient resistor becomes heated the resistance should increase proportionately, then return to about 10 ohms when cooled.

14.10 LINE FUSE TESTING AND FUSE FAILURES

Without exception, of all the various and frustrating types of failures that occur in microwave ovens, line fuse-related problems are certainly the most incessant. Check the fuse in the following manner: Unplug the oven, remove the outer cover, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S). Zero the ohmmeter on the lowest scale and measure across the fuse. A reading of zero ohms (continuity) indicates the fuse is intact. An open fuse will show infinity (no reading).

Probably about 50 percent of the fuse failures that occur appear to be from no apparent cause. In other words, the oven can be restored to normal operation simply by replacing the fuse. For the technician who was raised on the edict that something always causes a fuse to blow—that a fuse never blows without cause—this pesky paradox can be quite a "pain in the magnetron". So here are a few items to investigate and measures to undertake when intermittent fuse-blowing problems occur:

1. If possible ascertain the circumstances under which the oven went dead. For example:
   A. If the customer indicates that the failure occurred when the oven door was opened, the door interlock system becomes a prime suspect. In that case, if the interlock sequence is adjusted properly, the most cost-effective course may be to replace all switches associated with the monitoring system.

NOTE: The design of the monitor circuit in some models lends itself to the following monitor system checkout procedure.

1. Unplug the oven, remove the cover, and discharge the capacitor.
2. Set the ohmmeter to the R X 1 scale and connect one meter lead to each terminal of the power plug (excluding the ground prong). The oven line fuse must be intact and in place.
3. Determine from the schematic if the timer contacts are involved in the monitor loop; if so, the timer must be set to the "ON" position to complete the circuit. Relays that are included in the monitor loop may be manually held closed or temporarily jumpered out, if possible. If any such components cannot be rigged to simulate the actual monitoring function, this test may not work in that case.
4. If components such as the timer, blower motor, stirrer motor, and cavity light are electrically parallel to the monitor switch, these components should be temporarily isolated from the circuit so that the meter reads through only those components that comprise the monitor loop.
5. While closely watching the meter needle, open and close the oven door vigorously, then gently; then rapidly, then very slowly; snap it open, then press it closed. The number of times this procedure should be repeated depends on how intermittent the problem is, and how determined the servicer is to detect it. Twenty to 50 times will generally suffice.

6. If the monitor circuit has been properly isolated from any parallel circuits, there should be *no movement* of the meter needle whatsoever. Any movement indicates an overlapping condition between the actuation of the monitor switch and that of one or more of the related interlock switches. Properly adjusting the interlock sequence as outlined in *Section 14.3* should eliminate the intermittent fuse blowing bother.

B. If the oven "died" when the door was closed (which the customer may not have noticed until the next attempt to use the oven), the interlock monitor switch is certainly a likely suspect. However, additional factors must be taken into consideration, depending on the operational design of the oven. For instance, in many models a triac that is intermittently breaking down can cause the fuse to blow when the oven door is closed. Closing the door when the timer is set initiates the cook cycle in some models, so if the fuse blows at that time the components of the high-voltage section are also brought into question, in particular, the high-voltage transformer or capacitor.

C. If the customer says the oven "went dead" just as the cook cycle was started, the two likely suspects are the high-voltage capacitor and the high-voltage transformer. If the fuse blew immediately, check the HV capacitor. If several seconds elapsed before the fuse opened, the high-voltage transformer probably has a shorted winding.

D. When the indication is that the oven "went dead" during a cook cycle, especially if a lower power setting had been selected, the triac is more than likely intermittently breaking down and shorting to ground. When the fuse blows due to a malfunction in the triac circuit, the oven's malfunction may be directly preceded by a loud rumble or growling sound. While the defect in this case is usually in the triac or triac module, the gate-drive circuit of the controller can also cause a similar symptom.

Also, a fuse that has been weakened by intermittent low-voltage arcing between a faulty interlock switch and ground, will usually, eventually, open the line fuse during a cook cycle—a very misleading indication since the source of the problem is in the interlock system.

E. If the customer, reports that the problem seems to occur at the same time of the day, something other than the oven may be the culprit. For example, a voltage surge or drop caused by some peak-period load, either on the same circuit or on the same major power distribution system. Additionally, cyclic induction motors may cause an intermittent surge. And too, the power company, switching generators at the end of the day due to reduced demand, may produce a fluctuation in the supply voltage that could open the fuse if the oven is operating at the time.

2. Variations in the supply voltage of more than 10 percent of the rated voltage requirement for the oven can cause the fuse to open, if the oven is on-line during the fluctuation.

3. Another, quite common condition that causes the line fuse to open during a cook cycle is due, not to an over-current condition, but rather to an over-*temperature* condition. This problem common to all microwave ovens, is the result of a deteriorated connection, either between the fuse and fuse holder, or in the connections to the fuse holder. The deficient connec-

tion creates resistive heat, which builds up and gradually diminishes the fuse's current carrying capabilities. Eventually, for no apparent reason, the fuse opens during oven operation. As shown in Figure 14-16, this condition is often evidenced by a small bead of solder poking out from under the fuse's endcap, or a small pitted spot on the endcap and/or fuse clip, or both.

The integrity of the connection between the fuse and fuse holder can be checked by simply operating the oven at full power for several minutes, then, after quickly unplugging the oven and DISCHARGING THE HIGH-VOLTAGE CAPACITOR(S), feel the temperature of the fuse. If the fuse is too hot to comfortably touch, replace the fuse holder. When replacing the fuse, make certain that the fuse holder clips grasp the ends of the fuse firmly. If necessary, squeeze the clips together slightly to provide firm tension.

As a common practice on all ovens, regardless of the problem, a slight turn of the fuse while it is in the holder will verify its firm fit, provide a cleaning action, and turn an unused area to the contact point.

4. Electronic control panel models made by *Sanyo* may experience a fuse failure during periods of non-use (i.e., during the night). If no apparent reason for the failure can be determined, the problem may be in an IC chip on the control board called a *photo-coupler*. This occurs when the photo-coupler, usually white in color and designated *PH1* or *IC1,* is turned on in an erratic or abnormal way due to the formation of a current leakage path between certain pins of the photo-coupler. This leakage path may be the result of condensation (under humid conditions), a wandering nocturnal insect (usually the abominable cockroach), or the leavings of the same wretched creature.

   The philanthropic solution to this nasty problem is to *very diplomatically* advise the customer of their undesirable guests. The technical correction is to insulate the pins of the photo-coupler as follows:

   A. Unplug the oven, remove the outer cabinet, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR.
   B. Carefully remove the control board. Be careful not to touch any control panel components. Unless proper grounding precautions are

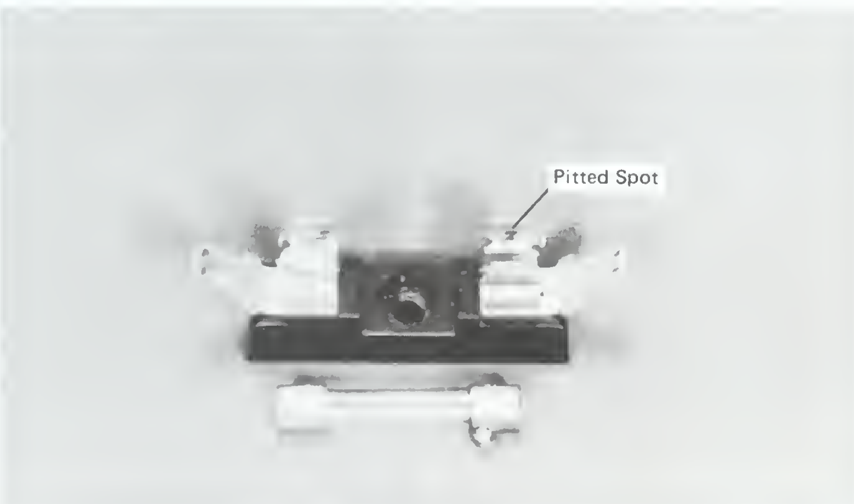


Figure 14-16 Evidence of a defective fuse holder.

taken, electrostatic discharge can damage static sensitive control panel circuitry. See *Section 8.6* for proper printed circuit board handling.

C. Refer to Figure 14–17 to identify the photo-coupler. Inspect the area of the photo-coupler, making certain it is clean and dry. If necessary, a toothbrush may be used with a suitable non-conductive, anti-static cleaner to clean the board without scratching it.

D. Using a silicone sealant (i.e., GE-RTV or Dow Corning-738 or 3145), apply a dab of sealant to the photo-coupler pins 5, 6, 7, and 8. Force the sealant in between and around the pins so that they are totally enclosed and sealed. Figure 14–17 points out the photo-coupler with the sealer applied to the appropriate pins.

E. Turn the board over and apply sealer to the area where the same pins extend through, and are soldered to, the board. Coat the pins so as to form an insulation between them. In Figure 14–17 the circuit board is suspended over a mirror, making the underside with the applied dab of sealer visible.

F. Reinstall the board, replace the fuse, and test the oven for proper operation.

5. It is not as uncommon as one might think to find that the fuse itself is defective. Fortunately, this unwonted failure usually limits itself to ovens that have been recently purchased—normally within the warranty period. In some cases, certain models all received defective fuses from the same bad lot. Therefore, do not discount the possibility, albeit strange, of the fuse simply being defective, especially in relatively new models.

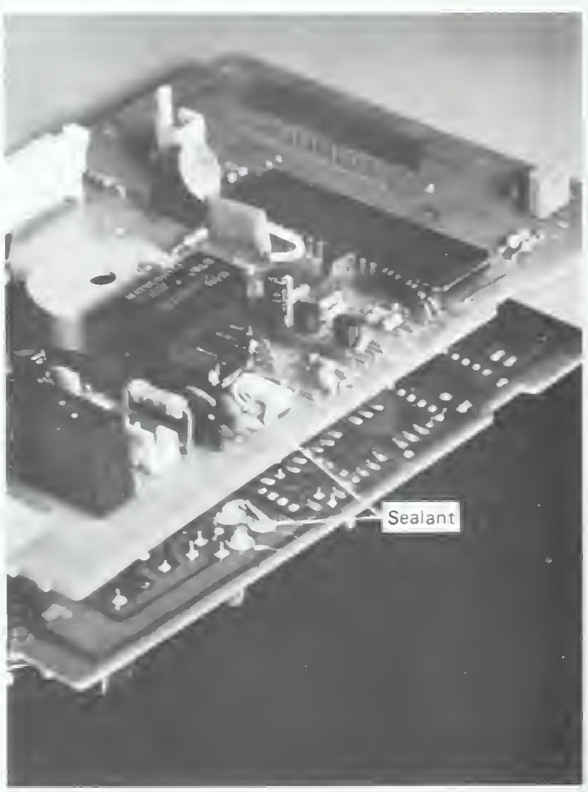


Figure 14–17 Sealer applied to the photo coupler.

Containment Systems: Checks and Failures

chapter 15

15.1 INTRODUCTION

The oven cooking cavity requires very little, if any, service. Rust and corrosion from residual moisture, and deterioration of the cavity floor from prolonged exposure to accumulated grease at high temperatures are probably the cavity's biggest enemies. Carefully wiping out the cavity and drying the inner door after cooking high-moisture products will prevent (or at least minimize) cavity rust and corrosion. Some models simply have poor air circulation so the moisture is not removed during cooking. Various modifications and improved air baffling have helped in these cases. In certain models, such as some of *Amana's* and *Sharp's* commercial units, an examination of the *seal* around the shelf will show it to be deteriorating with age and thus allowing seepage of moisture-ladden grease into the sump area below the cavity shelf. Even stainless steel cavities are not immune to the effects of prolonged exposure to this tallowy burned-on grease. Besides the persistent hint of a grease-trap, this eventually results in such deterioration that arcing and burning can eat holes right through the cavity floor. Furthermore, the agglomerate of grease creates an unnecessary load by absorbing energy and robbing the efficiency of the unit. See the subsequent section on "Replacing Shelves" for additional information.

15.2 CLEANING THE *CHOKE* CAVITY

Many models, such as the one illustrated in Figure 15-1, are designed with the *RF choke* cavity formed right into the oven facing. Accumulated moisture on the face of the inner door (when closed) drips down and is trapped inside the choke cavity—the choke filler prevents access for cleaning. Except for those units whose owner has been scrupulous about wiping down the door, most of these models will have varying degrees of recrement residing within the choke cavity. Unless the choke filler is going to be removed, the opening cleaned out, and a new filler installed (the

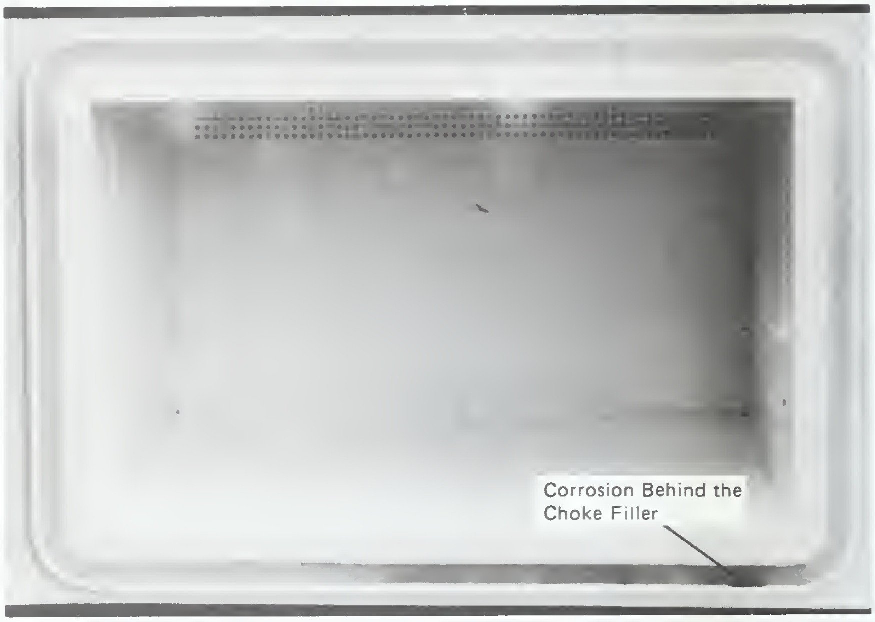


Figure 15-1 RF choke and choke filler.

original filler is destroyed upon removal), it behooves the diligent servicer to make some attempt, depending on available equipment and the degree of accumulation, at cleaning the defacement. This courtesy can be easily accomplished by tipping the oven on its back and applying a mild cleaner-degreaser to the area. Allow the cleaner to seep down into the choke cavity and soak a while. Then return the oven to its upright position and do any or all of the following: 1) Blow out the choke cavity using an air compressor with a blow-gun fitting. 2) Insert a piece of cardboard, about the thickness of a business card, into an accessible gap at either end. Then slide the cardboard, keeping it as deep as possible into the crevice, along the length of the choke cavity. 3) Tip the oven onto its back and flush the cleaner-degreaser out with hot water; then lean the oven forward so the water and cleaner will drain out of the choke cavity.

15.3 RUST AND CORROSION IN THE COOKING CAVITY

When rust or corrosion occurs there are several factors to consider: 1) If the rust is emanating from a cavity seam, it more than likely *cannot* be satisfactorily repaired. If the deterioration is severe enough (or the customer insists on some corrective action), the cavity itself (*if* available as a replacement part) should be replaced. 2) Rust along the shelf line (where the shelf is sealed in) requires that the shelf be removed. 3) Surfaces that come in contact with the black vinyl door gasket (when the door is closed) cannot be successfully painted. An agent in the gasket tends to draw the thinner out of the paint even after the paint has dried completely.

15.4 PAINTING THE COOKING CAVITY

Here is where the servicer's versatility can shine. First, make a determination as to the feasibility of completing a satisfactory job. Having decided to proceed, use either a wax and grease remover or mineral spirits to clean the surface of rust, grease, wax, oil, crumbs, and similar contaminants (required materials may be

obtained from hardware or paint and body suppliers). If necessary, remove loose paint and rust scale with a wire brush. At this point, if the condition merits, an acid-based rust remover may be applied—carefully follow the manufacturer's instructions. To achieve professional results use an appropriate grade of emery cloth for the job (sandpaper may also be used—do not use steel wool). Start with the coarsest grade suitable for the job. (The degree of coarseness will depend on the extent of the rust and surface erosion. For example, use a 180 grit for common surface rust.) Sanding along the longest direction, remove all rust, burns, carbon-filled pits, carbon tracks, loose paint, and other irregularities. Progress to the next finer grade as each stage of sanding removes the scratches from the previous grade. Finally, finish off the surface with an extra-fine 400 grit; feather the edges of existing paint until they are smooth to the touch. Sand any glossy surfaces to be painted. Use a good quality masking tape and masking paper to mask off areas not to be painted and to protect from overspray. Remove any sanding dust and apply a minimum of 3 medium coats of a gray primer. Allow each coat to dry to a flat sandable finish, lightly sanding between each coat with a 400 grit emery cloth. (Note: primer is usually only necessary in cases of more extensive surface erosion, although it may be used on any job if preferred).

Cavity paint can be purchased from each respective manufacturer for an exact color match. However, an off-white, eggshell, or antique white enamel paint will usually suffice. Compare the color match on an inconspicuous area of the cavity before applying the paint. Ideally the temperature of the surface and the paint should be between 70°F. and 80°F. for good paint adhesion. Follow the directions on the spray can for paint preparation and the proper spraying distance—if held too close, runs and drips will result; if held too far away, the coverage will be thin and spotty. Apply the paint using the following proven technique: Imagine an 8 to 10 inch string stretched between the spray valve opening and the surface to be painted. Hold the can so that the string is tight and exactly perpendicular to the surface. (It is advantageous to orient the oven so the surface to be painted is on an accessible and horizontal plane.) Start at one side of the surface to be painted and, keeping the imaginary string tight and perpendicular to the surface, begin spraying, moving along the longest surface at a steady, even rate. Overlap each stroke (or row) by 50 percent. The first coat should be relatively light to prevent existing paint from blistering. Apply a medium second and third coat, allowing each coat to dry for at least 15 minutes before applying the next coat. If available, a heat lamp or hot-air blow dryer directed on the surface between each coat will help evaporate the thinners in the paint and thus speed up the process, reduce the chances of blistering, and prevent the paint from blushing.

Polish off the job with a good quality wax. Buff the surface to a shiny lustre and beam with pride at the glowing smile of a satisfied customer.

An additional note; a cavity assembly that has been deformed or distorted by mishandling or other mishap can permit dangerous amounts of RF leakage, and, if unrepairable, should be replaced (if available). Even if the enclosure is not breached, the distortion may produce leakage through air vents and other openings. And too, if any seams are ripped or buckled the cavity should be replaced.

15.5 HOW TO REPLACE A SEALED-IN CERAMIC SHELF

While this section deals primarily with the replacement of *sealed-in* shelves, it should be noted that the causes of broken shelves or trays, whether sealed in or slid in, are the same in most cases. As mentioned above, grease deposits and food particles can carbonize and cause arcing. When this occurs on a surface of the oven shelf the extreme heat can cause the glass (or ceramic) to melt and crack. Operating an oven

empty for a prolonged period, or the improper use of metal on the cooking shelf, can produce the same results. A non-rotating stirrer blade or antenna may direct concentrated beams of energy on to the shelf causing the formation of sort of an inverted crystalline bubble that soon fragmentizes (Fig. 15-2). And, a flaw in the shelf itself, when subjected to microwave energy under the right circumstance, can cause the shelf to shatter.

When a slide-in tray must be replaced, carefully remove all fragments of glass. Be careful of tiny razor-sharp slivers of glass. These glass splinters can be extracted in the following manner: Wearing safety glasses, use the sticky side of an adhesive tape to collect and remove the tiny fragments of glass. Next, before sliding in the new tray, the cause of the break must be determined. Then, after the appropriate corrective actions have been completed, the new tray may be set in place.

When a sealed-in shelf must be replaced, use the following procedure for the best results.

Safety notes: 1) Occasionally the glass will splinter as the original shelf is being pried up, therefore safety glasses are strongly recommended.

2) The sealant releases acetic acid, a non-toxic vinegar-like odor, so adequate ventilation is required during and after application to allow the RTV sealant to fully cure (about 24 hours) and the non-toxic odor to subside.

1. Use a sharp thin-bladed, hook-type knife (such as a box cutter or linoleum knife) to cut down through the existing sealant around all four sides of the shelf.

2. Use a strong putty knife or thin screwdriver to pry under the front edge of the shelf until it can be raised up and out. In some models the shelf has additional sealant underneath; in these cases it is usually necessary to break the original shelf in order to remove it. If not already on, put on the safety glasses. Extract the shelf by placing a cloth or towel over it, reach in with a hammer, close the door to the extent possible, and with a sharp blow to its center, break the shelf.

3. *Carefully* remove the old shelf and all debris from the oven cavity. A piece of adhesive tape is helpful in removing glass splinters and chips. The wall area next to the shelf must be free of grease, soil, and old sealant (old sealant can be removed with nail polish remover, although that which is stuck to the cavity bottom or other noninterfering areas need not be removed). Clean the walls with a non-abrasive household cleaner or isopropyl alcohol (rubbing alcohol).

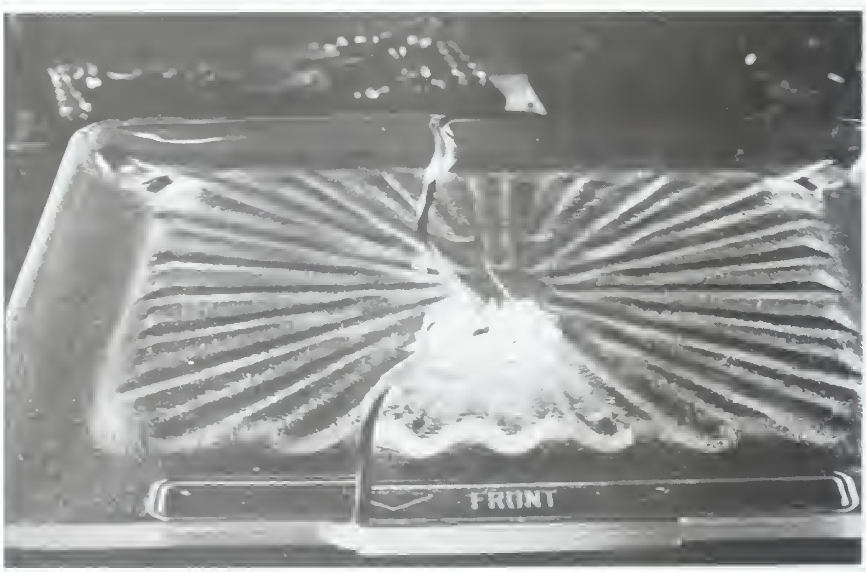


Figure 15-2 A broken tray; the victim of a stalled stirrer.

4. Figure 15-3 shows the optional step of taping off the new shelf and the cavity walls in order to achieve uniform seams of sealant.

5. Depending on the model, it may be necessary or advantageous to apply a $^1/_4$-inch bead of sealer along the ledges on which the shelf sits. Then place the shelf on the sealer-coated ledges, pressing it into place (*smooth side up*), forcing the sealer up into the seams.

6. *Begin the countdown:* The type of RTV sealer used in microwave ovens for this purpose—General Electric RTV-102 or Dow Corning RTV-732, for example—allows *about 10 minutes* of shaping and finagling before it begins to congeal. Once the sealer, quite indiscernibly, begins to solidify, any last-minute "finishing" strokes will turn an adequately smooth seam into a unacceptable bumpy botch. In other words, apply the RTV carefully and neatly, as indicated in the following technique, but do so with as much dispatch as is practicable—then leave it alone! (Note: do not use bathtub calking or other types of plumbing sealants.)

7. Place the cone-shaped applicator nozzle on the RTV tube and cut off the tip at an angle. Cut off the tip so that the diameter of the opening is about $^1/_{16}$-inch, which is usually sufficient.

8. Apply a continuous and even bead of RTV sealer. Starting at the rear right-hand corner, run a bead across the back and around the rear left-hand corner, continue working the bead along the left side moving toward the front, then stop at the front. Go back to the rear right-hand corner and run a bead along the right-hand side, stopping again at the front. Then apply a bead across the front of the shelf, between the shelf and the front frame.

9. As shown in Figure 15-4, a scraper card may then be used to dress the seams. The scraper can be made by cutting out about a 3-inch square from a piece of fairly rigid cardboard, then cutting off one of the corners to form an angle. Some prefer a piece of hard plastic for this purpose. Just prior to dressing the seams, spray a small amount of water or an alcohol-water mix (i.e., window cleaner) onto the area to be dressed. This will help produce a smooth finish.

10. Hold the card as shown and, with sufficient pressure, form each seam with firm, steady, and continuous strokes. After each stroke (or about every 3 inches if necessary), pause and wipe the excess RTV off the card with a paper towel. Movement across the rear seam may be in either direction. To form the side seams, the strokes should be from the rear toward the front. The seam across the front is

Figure 15-3 Masking helps achieve uniform seams.

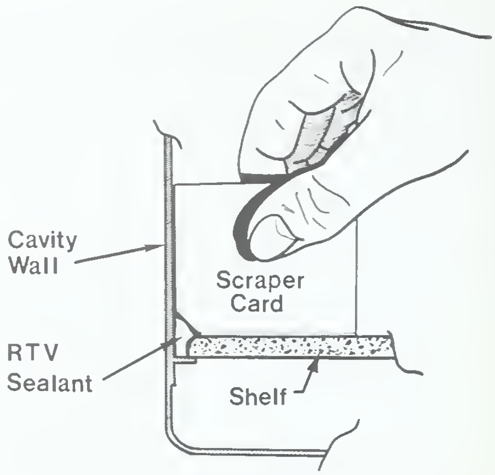


Figure 15-4 Dress the seam with a scraper card. (Courtesy of Michael S. Wagner)

dressed out in various ways, depending on the model, but may be formed as were the others with the stroke going in which ever direction is most comfortable. The seams should have a neat, smooth appearance.

11. Inspect all seams for voids and irregularities—each seam *must* form a tight, but neat, seal. Fill any gaps or hollows with additional sealer, then scrape the seam smooth again.

12. If desired, a super-smooth finish can be obtained by gliding a moistened finger over the seams after initially scraping them. Wipe excess RTV off the finger as necessary.

NOTE: This all must be done within about 10 minutes—before the sealer starts to congeal.

13. Over-smears and sealer residue can be either scraped away with the cardboard or peeled away after the sealer has set up. If masking tape was used to tape off the shelf and cavity walls, it should be carefully removed after the sealer has set up, but before it dries—be careful not to shift the shelf while removing the tape.

14. Allow the oven to sit at least 24 hours (or until fully cured) with the oven door partially open to aerate. Advise the customer not to disturb the sealer (by wiping or cleaning) for at least 48 hours.

15.5.1 Shelves with a Preformed Gasket

Most commercial *Sharp* models, many *Panasonic* commercial models, and some *Quasar* units, use a cooking shelf which is made with a silicone rubber gasket that is already preformed around its edges. Removal simply entails prying the shelf up and out according to the appropriate procedure. For example, Figure 15-5 shows the removal of a typical *Quasar* shelf.

When servicing commercial units with this type of shelf, particularly *Sharp* models, the service should include a visual inspection of the shelf gasket and the cavity well as shown in Figure 15-6. Generally, this need only be performed if the oven bears the signs of heavy use, or has been in service for several years or more. If the gasket shows deterioration, such as severe serration, breaks or lacerations, the shelf assembly should be replaced. The cavity well should be inspected for accumulation of grease or other residue, and cleaned accordingly. Be careful when raising the shelf not to damage an otherwise undamaged shelf gasket.

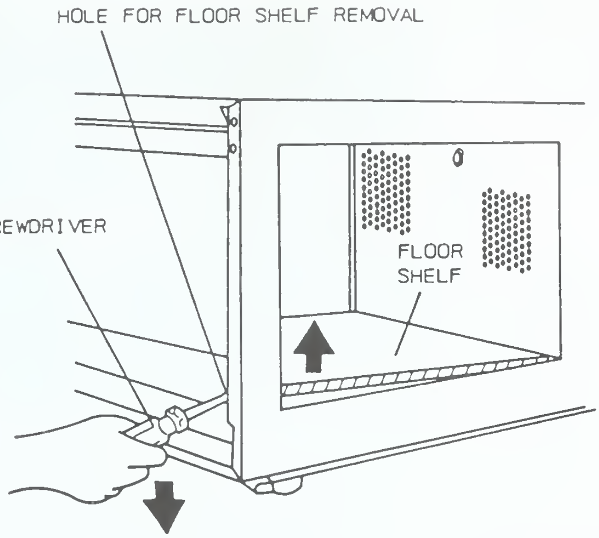


Figure 15-5 Removal of a Quasar Shelf. (Used by permission of Matsushita Electric Corp. of America—source material copyrighted 1986.)

15.6 WAVEGUIDE DISORDERS

Loose antenna pins (tuning stubs) are about the only fault, albeit rare, that occurs in the relatively problem-free waveguide. When this occurs, it begins when the antenna pin gradually becomes loose. As it does, the ground juncture between the pin and the waveguide surface begins to anodize, and thus the connection diminishes. Consequently, to the extent that contact between the pin and the waveguide chassis is impaired, the pin will heat up noticeably (sometimes even glowing red) when subjected to the microwave energy from the magnetron. This tends to further loosen the antenna pin. In Figure 15-7, the effects of a loosening antenna pin have

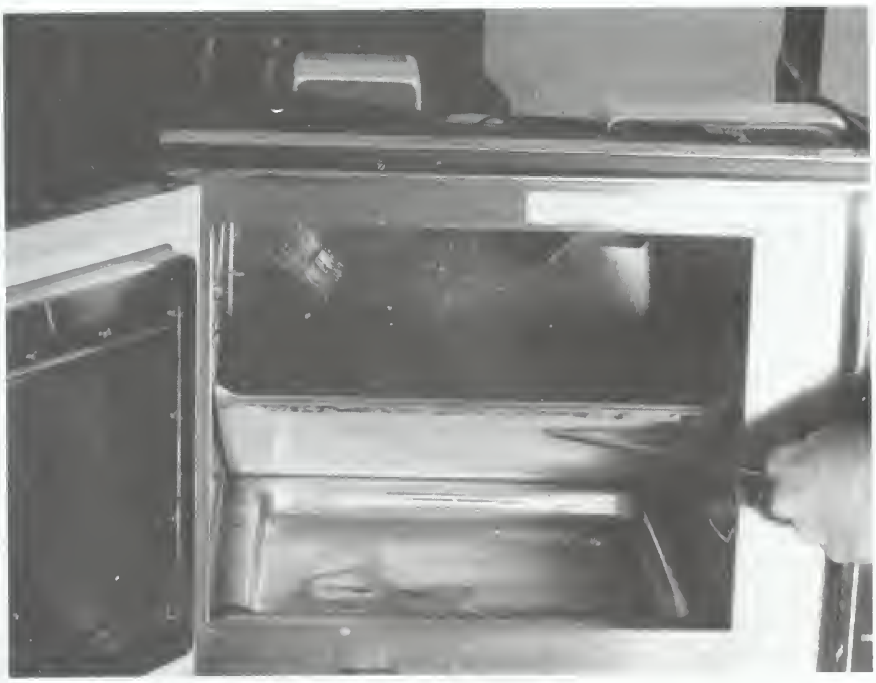


Figure 15-6 Inspect the well of the cavity.

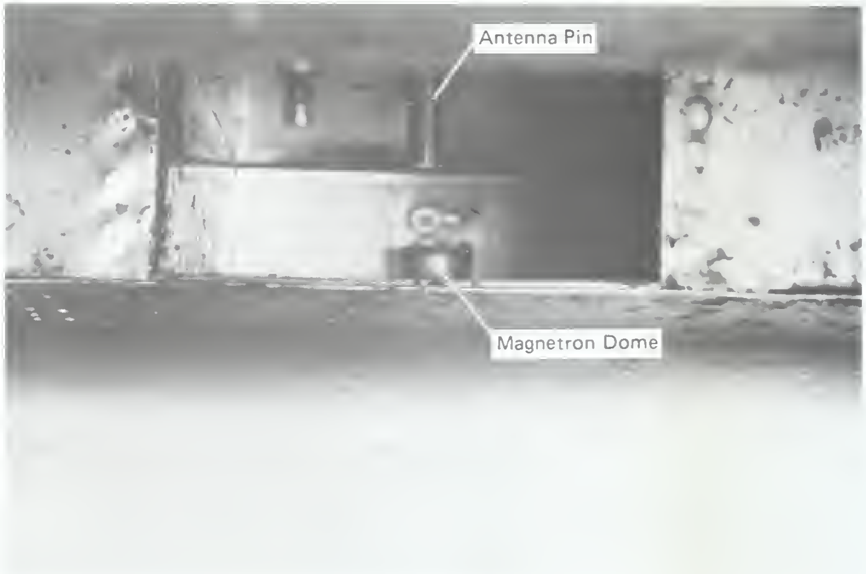


Figure 15-7 A loose antenna pin will damage the magnetron.

gradually deteriorated the dome of the magnetron tube. Thus, even when an antenna pin has merely loosened to the point where the adjacent waveguide surface is discolored, the magnetron tube may have already been damaged. Eventually, if the condition goes unchecked, the pin either burns its way through and drops down inside the waveguide in a melted magnetron-wrenching mass, or the pin disintegrates leaving an unrepairable charred hole in the waveguide.

Needless to say, the astute technician will keep a watchful eye out for this seldom-seen but often-overlooked condition. Although not a common problem, the occasional *Litton* "meal-in-one," of the 500 series, has been known to develop this condition. Look for discoloration around the waveguide where the tuning stub (which is simply a bolt in the *Litton*) is mounted. If the tuning bolt will not tighten, chances are the bolt, and not the threaded hole in the waveguide, is stripped out and can easily be ordered and replaced.

In many models, such as *Sharp* and *Tappan,* the tuning stub is spot-welded to the inner wall of the waveguide, and therefore inaccessible. A circular scorch mark on the corresponding exterior surface of the waveguide indicates a possible deteriorating tuning stub, for which little can be done except replace the oven cavity, if one is available as a replacement part. However, this discoloration can also denote some other source of burning or reflected energy within the waveguide, such as an arcing waveguide cover or stirrer cover (grease or splatter shield—see *Section 16.8*), or a stalled antenna or stirrer blade (see *Sections 16.4* through *16.6*).

Clearly, it is a worthy habit to check the tightness of the antenna pin (or tuning stub) mounting on any model in which the antenna pin becomes accessible during the course of normal service.

15.7 DOOR LEAKAGE AND SAFETY SYSTEM—CHECKS AND FAILURES

Foremost among test procedures in this category is the *Microwave Leakage Test.* This test insures that an oven meets the microwave leakage criteria established by the U.S. Government Department of Health and Human Services, 21CFR Part 1030.10 performance standards for microwave ovens. These guidelines state, in part, that the

power density of the microwave radiation emitted by a microwave oven shall not exceed 1 milliwatt per square centimeter at any point 5 centimeters (about 2 inches) or more from any external surface of the oven, measured prior to acquisition by a purchaser, and, thereafter, 5 milliwatts per square centimeter at any such point. In other words, after an oven is acquired by a purchaser, and over the life of the oven, it must not exceed a radiation emission level of *5 MW/CM²* at a distance of 5 centimeters. (5 centimeters is automatically gauged by the depth of the spacer cone at the tip of the RF meter probe.)

The federal guidelines notwithstanding, proper maintenance and adjustments should normally limit the leakage to substantially less the 5 MW/CM².

The radiation-monitoring instrument (variously referred to as an RF meter, microwave leakage tester, and microwave survey meter) must be certified by the Federal Bureau of Radiological Health (BRH), and approved by the microwave oven industry. Refer to *Section 5.2.3* for a list of presently approved RF survey instruments. The meter must also bear a calibration sticker confirming that it has been calibrated within the time specified by the manufacturer. Most, if not all, manufacturers specify that the meter be checked for proper calibration at least once within every 12 month period. The annual calibration is to be performed by the respective manufacturer of the instrument, or a company authorized to do so by that manufacturer.

Depending on the amount and type of use an oven receives, an RF survey is suggested about every six months, although this is not required. It is a requirement to perform a leakage test any time that an adjustment and/or a repair is made on any door assembly, magnetron, or any other component that may effect the RF containment. A requirement of many microwave oven manufacturers, and a personal recommendation—for posterity's sake—is to check every oven, regardless of the nature of repairs, before and after the service.

In many countries, methods of surveying RF leakage may differ, as do the maximum allowable leakage standards. In some of the United States the allowable levels are more stringent than the federal limits. In each case the required guidelines should be met. If in doubt, contact the appropriate government agency in the jurisdiction in which the oven is to be operated.

It is important to carefully follow the manufacturer's instructions as regards the specific operation of a given RF meter.

15.7.1 RF Leakage Test Procedure

1. Visually check the oven for obvious damage to the door or door seal. Make sure the oven is clean and there is no buildup of dirt around the door seal area. Place the standard test load of 275 milliliters (275 ml = approximately 1⅓ cups) of cool tap water in a non-metallic container and place the container in the center of the oven cavity. If the oven is equipped with a metal rack, the rack must be removed.

2. Inspect the probe's spacer cone to insure that it is intact and firmly seated on the meter probe. If the meter is equipped with a switch that controls the response time, set the switch for a "Fast" response. Follow the manufacturer's instructions regarding preliminary meter checks. For example, the *Holaday HI-1501* has "Battery" and "Probe Test" positions on the selector switch. These functional tests should be satisfied before continuing.

3. If the magnitude of the leakage is unknown, it is advisable to start with the RF meter set and zeroed (as explained in step 4) on a higher, less sensitive scale. Slowly introduce the probe into the energy field and make a brief preliminary check, and then work down to a lower more sensitive range. Each time the range-scale is changed, the meter should be rechecked and re-zeroed. High magnitudes of microwave emissions are rarely encountered, but on those surprising occasions, the higher

scale will avoid exceeding the meter's full scale deflection and possibly damaging the meter, the probe, or the operator.

4. Set the RF meter to its most sensitive scale. That is, the scale which provides the greatest needle deflection. If applicable, allow the meter to stabilize for about 2 minutes. Zero the meter by adjusting the "zero adjust" knob so that the needle reads zero.

5. Set the oven timer for about 3 minutes and, if applicable, set the power control to full power. Start the cook operation and proceed with the leakage measurement.

6. Hold the probe perpendicular to the surface being measured, as demonstrated in Figure 15-8. This type of probe orientation not only provides an accurate measurement, but also provides safe distance between the radiating source and the body of the operator. Always use the 5 cm spacer cone, it provides a standardized distance. With the meter switched to *fast response,* slowly move the probe around the periphery of the door at a scan rate of no more than one inch per second (or 2.5 CM per second). When measuring around corners, keep the probe perpendicular to the surface. Slowly move the probe around and horizontally, vertically, and diagonally across the surface of the door. Also pass the probe over all other seams, vents, and openings (i.e., around switch openings and indicator lights) in the front, top, bottom, sides and rear of the oven as shown in Figure 15-9.

7. In areas where higher leakage is detected, hold the probe stationary until the reading stabilizes, then note these higher readings and where they were obtained. Or, switch the meter to *slow response* and take a reading for a minimum of 3 seconds. If any reading exceeds (or even approaches) the maximum allowable limit, the necessary repairs and adjustments must be made before the unit is released to the customer or put back into service.

8. While moving the probe along the door edge that is opposite the hinges, where the maximum door movement takes place, slowly open the door as illustrated in Figure 15-10. Insure that the interlock system interrupts the cook cycle before any appreciable rise in RF leakage is detected. Generally, the primary interlock should open the cook circuit within approximately 1/16-inch of door's outward movement.

9. Follow the same procedure as in step 5, check any areas where repairs, adjustments, or replacements were made.

10. Many agencies desire or require that the actual meter reading and the date read be recorded on an "RF radiation check" sticker, which is then affixed to an optional location on the oven.

NOTE: before returning the meter to its case, make sure it is turned off, and periodically inspect the spacer cone for wear.

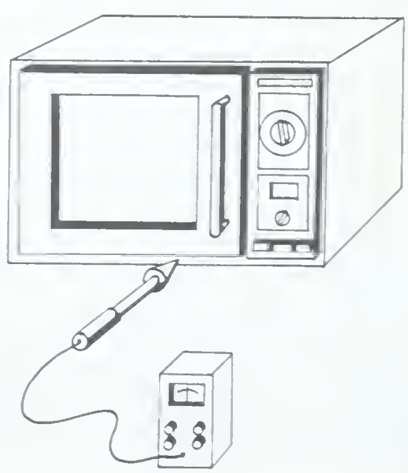


Figure 15-8 Hold the probe perpendicular to the surface being measured. (Courtesy of Michael S. Wagner)

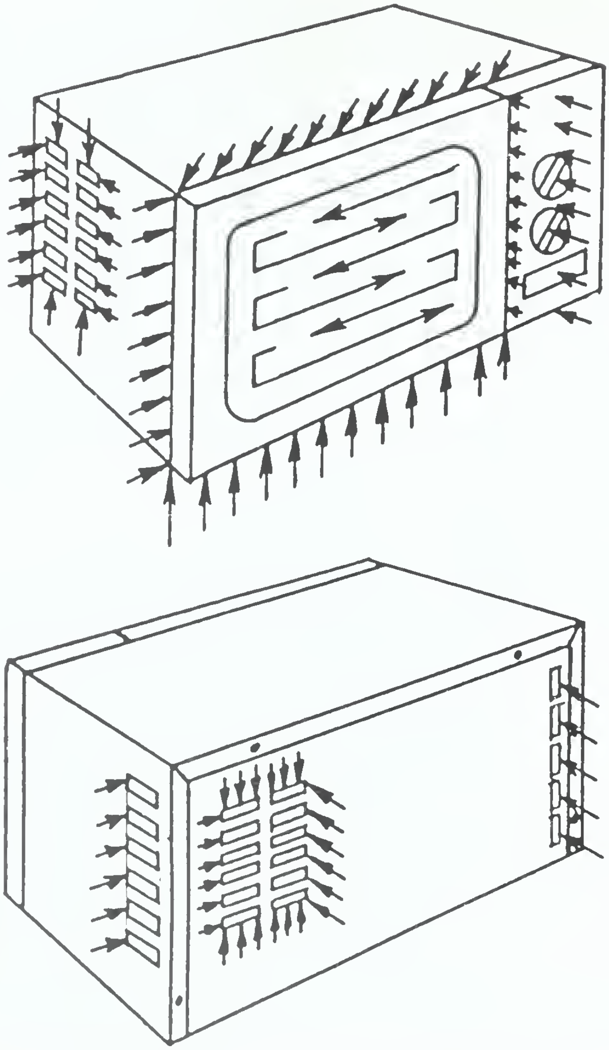


Figure 15-9 Move the probe along areas indicated by arrows. (Reprinted with the permission of White Consolidated Industries.)

15.8 DOOR ADJUSTMENT

Among the many door, latch, hinge, and pin arrangements, specific door adjustment instructions vary considerably with different makes and models. In lieu of that, a few basic common-sense considerations will serve as a general guide to door adjustments.

1. Unplug the oven, remove the cover, and discharge the capacitor.

2. Loosen the hinge (or hinge bracket) mounting nuts (or bolts) so that door movement is allowed, but maintain a degree of tension so the door will hold its position to some extent.

3. Align the door so it is parallel with the oven face lines. Position the door so that the door hooks (or latch heads) pass properly through the center of the access holes and latch in place.

4. Pressing from the middle of the door, hold the door firmly against the cavity faceplate. Check the vertical, horizontal, and diagonal alignment, and snug down the mounting nuts.

5. Check to ensure that the door opens, closes, and latches with relative ease.

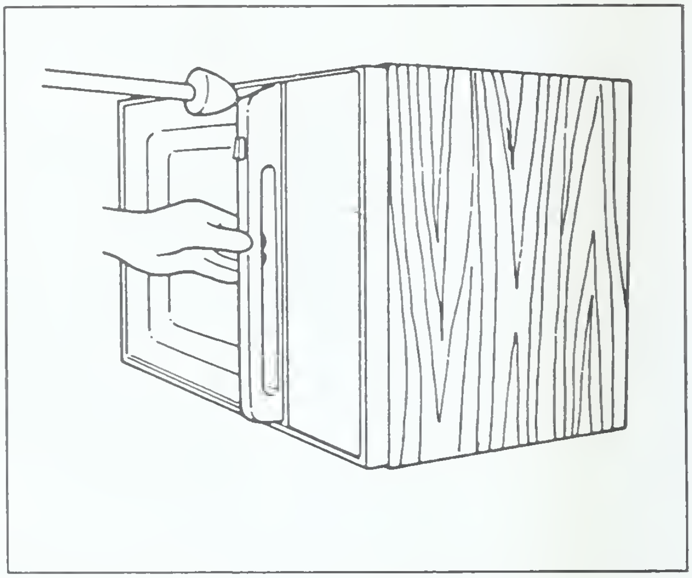


Figure 15-10 Measure the extent of RF leakage before interlock switch interruption. (Used by permission and courtesy of Matsushita Electric Corporation of America © 1983.)

Slamming or excessive pressure should not be necessary for proper closing and latching, and two hands or prying should not be required to get the door open.

6. Then tighten—do not over-tighten—the mounting nuts, and re-check the opening and closing action.

To check the fit of an oven door against the cavity face, wedge a strip of paper (cut to approximately 1-½ × 5-inches in size) between the cavity face and the inner-door facing. As illustrated in Figure 15-11, perform this test at different points around the door periphery. With the door closed on the paper strip, pull the strip out as shown. A properly fitted door will offer some, but not a lot, of resistance. If

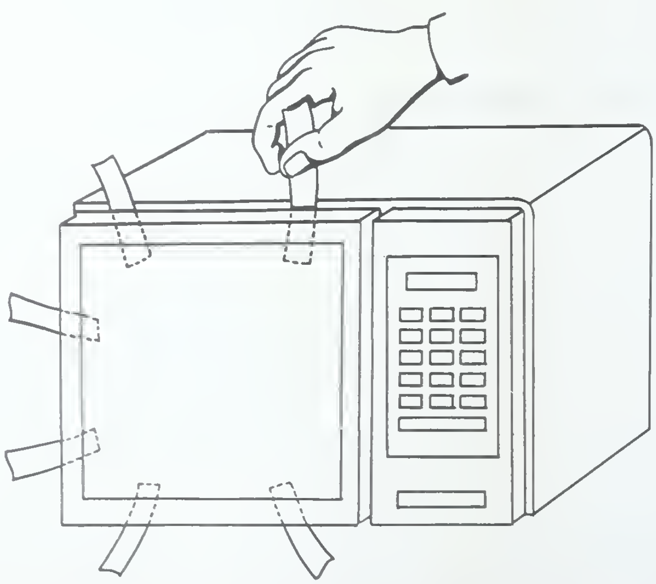


Figure 15-11 Check for a snug fit using strips of paper. (Courtesy of Michael S. Wagner)

there is little or no resistance, the door is not closing tight enough. If, on the other hand, the paper cannot be removed without ripping, the door is seating too tightly against the cavity facing.

Once a satisfactory adjustment is achieved, and prior to releasing the oven to the customer, the door must be checked for RF leakage as outlined in *Section 15.7*. This requirement is to ensure that the unit does not emit RF leakage in excess of 5 mw/cm^2 at 5 cm., and to verify compliance with the federal performance standards for microwave ovens as established by the Department of Health and Human Services (DHHS). It should be noted that, under normal conditions, routine adjustments and proper servicing should limit the leakage to less than 1 mw/cm^2.

15.8.1 Service Tip on *Amana* Doors

Amana is famous for its domestic door which swings down to open, and upward to close. Over a period of time, however, the door frame tends to develop a slight bias that becomes the most noticeable in the upper right hand corner of the door when the door is closed. The effect is that the top right edge of the door does not seem to close as tightly as the corresponding left side. This may also adversely affect the adjustment between the door-latch hook and the latch-interlock switch, which will produce complaints of intermittent heating.

The warp can be removed to an extent in the following manner: In the upper left-hand corner of the door, wedge a padded obstruction of some sort between the door and the oven facing. Then press inward on the upper right-hand corner, applying suitable pressure to flex the door frame back into an acceptable alignment. This, as with any adjustment of this nature, must be finalized with an RF leakage check to insure compliance with federal government guidelines (see *Section 15.7*). The maximum leakage allowed is 5 mw/cm^2, although as a rule normal service procedures will limit this amount to less than 1mw/cm^2.

15.8.2 Steam and Light Escaping Around the Door

Customers may complain of steam or vapor escaping from around the oven door. Or, there may be concern about areas around the door or outer case where light reflections are visible. It should be explained that the door seal is designed to prevent microwave leakage by absorbing spurious harmonic frequencies in accordance with Federal guidelines. However, the door gasket does not have to be airtight to accomplish this, and so is not a vapor seal. The oven cavity light in most models is located outside the oven cavity and may reflect light out around the hinge, door, outer case, or lamp access cover. Therefore, the occasional appearance of moisture around the oven door (especially when cooking foods with a high moisture content or under humid conditions), small areas of light visible, or the movement of warm air around the door, are all normal conditions and do not necessarily indicate that the oven is leaking microwave energy.

15.9 *AMANA* INNER-DOOR MOLDINGS

It would be somewhat disingenuous to say that encountering a cracked or loose *Amana* inner-door molding is an uncommon occurrence. Regardless of the arguable cause, the fact remains that the inner-door molding of every *Amana*, commercial or domestic, regardless of the reason for service, should be visually examined for cracks, burns, or looseness. Since the molding serves merely as a protective and decorative cover, this problem in its early stages does not represent a danger. However, it is something that the customer should be aware of because as the

deterioration advances, grease, moisture, and dirt are allowed to build up inside the door weldment. Stains develop across the viewing screen in domestic units. Eventually this can result in burned spots, RF leakage, and the door glass (in domestic units) falling out.

15.9.1 Replacing Inner Door Moldings

The following outline covers all types of *Amana* molding replacements. Procedures that are unique to one particular type, such as some commercial models, will be pointed out and detailed as such.

1. Unplug the oven and open the oven door fully.
2. On older domestic models it is necessary to affix a small C-clamp on each counterbalance arm. Each counterbalance arm has a spring attached to it and will snap back into the cabinet without the restraint of the C-clamp. Later models provide a small hole in the counterbalance arm, through which a piece of wire or other suitable tool may be inserted to act as a stop. It is suggested that a piece of cardboard be placed between the C-clamp (or wire) and the black vinyl gasket to prevent damage to the gasket. Figure 15-12 shows an oven prepared for disassembly; for illustrative purposes, the left counterbalance arm demonstrates the C-clamp arrangement, and the right arm shows an allen wrench inserted through the retainer hole to act as the stop. Normally both counterbalance arms would have the same set up.
3. At this point the inner-door assembly can be unsecured and removed.
   - A. On commercial units the black gasket is mounted on the door itself, around the white plastic molding. If the gasket is going to be re-used (normally, on these units, by the time the molding needs replacing, the gasket does also), it must be carefully pried up around its outer edges as shown in Figure 15-13. This will expose a series of screws around the outside edges of the door. These screws must be removed. Steps B-G continue with reference to commercial models.
   - B. Remove the handle escutcheon. The outer ring and front panel of the door may then be removed to expose the molding-mounting studs.

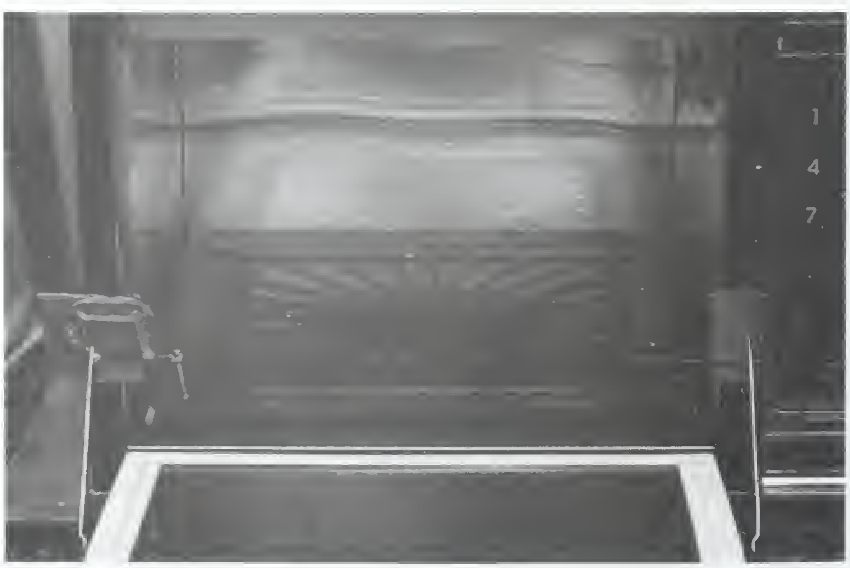


Figure 15-12 Inner door prepared for disassembly.

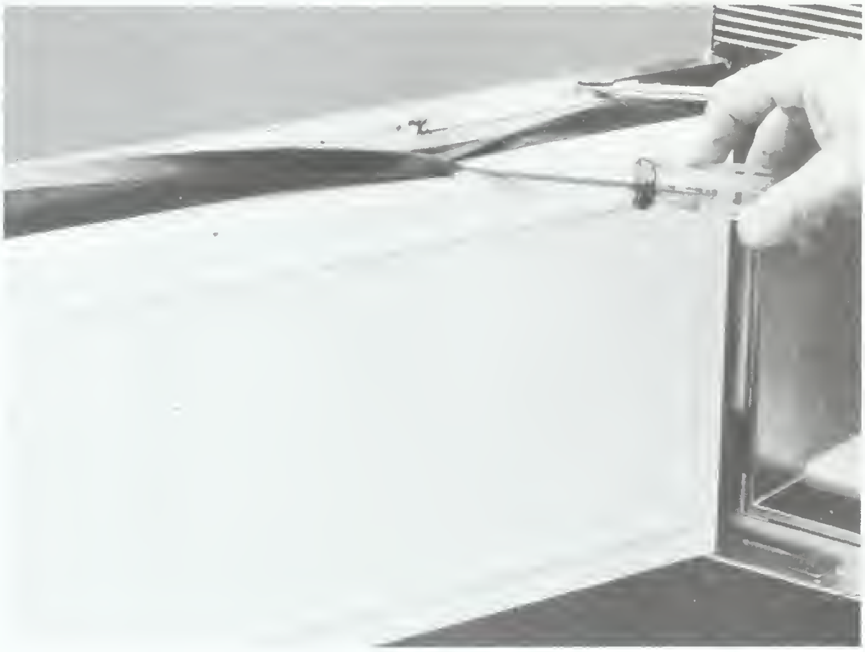


Figure 15-13 Carefully pry up gasket to expose retaining screws.

C. Unfasten the mounting nuts (or clips) and pull the white plastic molding away from the casting.

D. Before installing the new molding insure that the inner weldment facing is clean of grease, burns, crumbs, and so forth. Before replacing the black gasket it is advisable to strip away any remnants of used adhesive tape from the contact surface of the weldment. After the surface is cleaned, apply new lengths of double-sided adhesive tape along the inner and outer edges where the gasket will seat.

E. Install the new molding and, while pressing the molding firmly against the weldment, snug down the mounting nuts until they seat.

F. Carefully situate the black gasket around the molding, being careful not to rip the upper or lower molded corners of the gasket. Then press the gasket in place using the palm of your hand, a screwdriver handle, or other suitable implement.

G. Ensure that the door closes properly.

4. On domestic units, remove the special screws and carefully lift the inner-door assembly and remove the assembly from the outer casting. At this point some newer models require the removal of a mounting pin where the counterbalance arm engages the outer-door casting.

5. Disassemble the inner-door assembly, clean out any dirt, grease, and be particularly cognizant of charred or carbonized areas in the weldment. In some cases the burn damage is so extensive that the weldment must be replaced; usually, however, the carbon can be cut, sanded, and cleaned out. The resulting cavities can be filled with an RTV sealant.

   A. NOTE: Check the area inside the oven cavity that corresponds to the burned spot on the weldment. Pitted and carbonized blotches must be sanded (or ground) smooth and then cleaned.

   B. While the inner-door assembly is removed, use a toothbrush or similar gadget to sweep out the area along the piano hinge that joins

the outer-door casting to the oven cavity. Also, ensure that the two phillips head screws that mount the door handle to the casting are tight.

6. Lay the assembly on a soft cloth to prevent scratching and install the new molding. Press and hold the molding firmly and evenly against the weldment while tightening down the mounting nuts.
7. Reinstall the inner-door assembly into the door casting. Open and close the door several times and then examine the white molding for grayish-black smears. The area where a smear appears is rubbing against the cavity entrance wall as the door closes and opens. The inner door should be adjusted to eliminate (or minimize) that contact.

NOTE: Occasionally the plastic mounting studs appear to be too short to allow proper mounting of the retaining nuts. In this predicament, first ensure that there are no obstructions, such as adhesive tape or food particles, under the inner door. Second, make sure the black door gasket is not interfering with the fit. If the studs are still too short, then place the molding and inner-door assembly on a cloth-covered table with the studs pointing up. Gently, but firmly press down on the metal weldment (through which the studs are protruding) until the white plastic molding is installed evenly and as tightly as possible. Using a hot soldering gun or iron, with any excess solder removed, carefully melt the studs until they flatten out. Maintain pressure on the door assembly until the melted plastic has cooled and hardened.

8. Perform an RF leakage check as outlined in *Section 15.7*

15.10 GENERAL DOOR DISASSEMBLY

Other microwave oven doors that enable service disassembly vary somewhat in their respective disassembly procedures. However, as pictured in Figure 15–14, most involve the removal of a metal retainer plate commonly referred to as the *seal plate*. The seal plate is part of the RF seal and it retains the inner window. A worn or warped seal plate may allow excessive RF leakage and therefore require replacement. Or, as in the case of some *Litton* commercial models, ringed or disk-like scorches on the seal plate surface can result from no-load operation, the improper use of metal utensils or, more commonly, an intermittent *stirrer motor*. When the stirrer motor sporadically stops or fails to start, high concentrations of energy are beamed directly to areas on the seal plate surface, thus the burning and blistering. If the targeted seal plate surface is near an inner edge, and thus adjacent to the inner window, the result is usually a shattered inner window. When this is encountered, an inspection of the seal plate's inner edges usually reveals a burned spot from which the break emanated, symptomatic of a faltering stirrer system (see *Sections 16.4* through *16.6*). Some cases involve factory modifications. For example, in 1976 *Litton's System 70* models, now somewhat antiquated, underwent a field modification of the stirrer system due to excessive seal plate burn spots and inner window breakage. The measure entailed the installation of an improved stirrer hub (blade), which is now a standard replacement part.

In many models the seal-plate retaining screws, which usually require a special tool, are easily accessible and, with the appropriate screwdriver tip, are removed with no problem. If preferred, the oven may be tipped up on its side. This improves leverage for loosening stubborn screws, and keeps the interior door parts in place after the securing screws are removed. Warning: place a soft pad under the side of

Figure 15-14 Oven tipped on its side to remove sealplate.

the oven, and between the outer-door facing and the workbench surface to avoid scratching.

> **A note about scratches:** Some outer-door lens, windows, and other plastic facing parts are very susceptible to scratching. In case a surface is inadvertently scratched, a plastic polish is available from *Amana* (part number R1970-54). Before using the polish, clean the scratched surface of dirt and grit with a soft clean cloth. Then apply the polish to a clean damp cloth and lightly rub the polish onto the surface in a circular motion until the area begins to shine to a high gloss. Buff the surface with another clean cloth to remove any residue or haze.

While the door is dismantled, clean out any crumbs, grease, or other residue that has accumulated in areas that are normally inaccessible. To reassemble the door, snug down the seal plate mounting screws in an *even* sequence to prevent warping of the inner door. Make sure the inner window is properly positioned within the seal plate, and tighten, but *do not* over-tighten, the screws. During the reassembly process insure that all parts are reinstalled in their original location, position, and orientation. Perform an RF leakage check as outlined in *Section 15.7.*

15.10.1 Commercial *Litton* Door Disassembly

Litton's commercial 70 and 80 series units require a slightly different approach, one that requires removal of the *outer-door casting.* The casting is "popped off" in the following manner: First, using a 3/32-inch allen wrench, remove the door handle.

Second, insert a small flat-blade screwdriver (preferably covered with cloth to prevent marring) into the upper left hinge slot, between the inner-door frame and the overlapping outer-door casting. (If it becomes necessary to remove the oven wrap, be sure the oven is unplugged and the capacitor or capacitors are discharged.) Third, as shown in Figure 15-15, gently pry the complete outer-door casting outward until the mounting studs release from the four spring-clip retainers mounted on the inner door. Successively prying from each corner will facilitate the removal. Removing the outer door exposes the rectangular array of flanged seal plate retainer nuts. Unfasten these nuts to remove the seal plate or inner window.

At this point, the white plastic *choke filler* (Fig. 15-16) may also be replaced if necessary. Although the choke filler's main function is to help maintain the choke cavity's shape and keep it clean, the filler also serves to absorb small amounts of RF

Figure 15-15 Removing the outer door of a commercial Litton model.

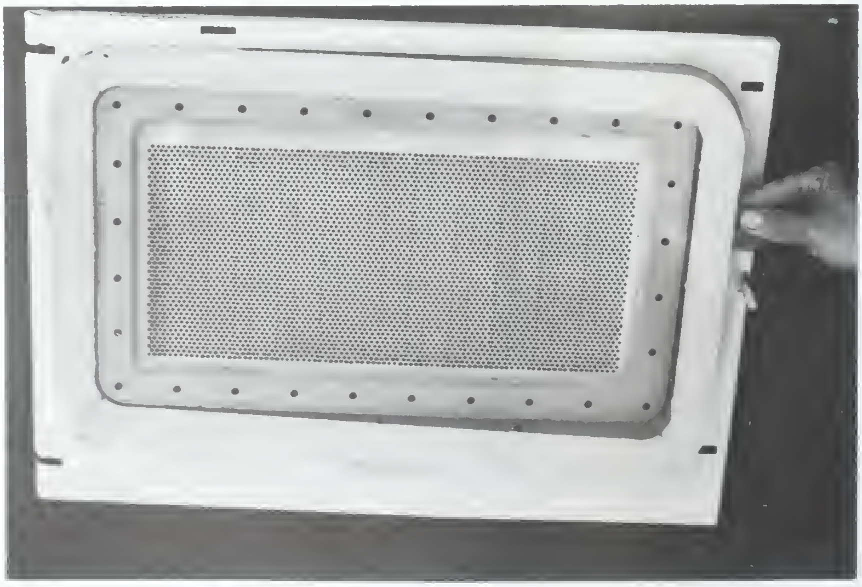


Figure 15-16 Removing the choke filler.

leakage. Therefore the choke filler must be properly in place before operating the oven. On the 80 series models the choke filler is held in place by the seal plate. So, with the seal plate removed, the filler need only be pried out of the choke cavity. Be careful to install the new filler with the proper side facing up.

The choke fillers in some 70 series models and quite a number of various domestic models are held in place by plastic mounting studs. Whether the filler is located on the inner door assembly (*Litton* 70 series), or recessed in oven cavity facing (as in most *Litton* and some other domestic models), it is removed by cutting or breaking off the plastic mounting studs that extend through the mounting surface. Withdraw the filler and perform the necessary maintenance (i.e., cleaning, painting) on the recessed channel that forms the choke cavity. Insert the new choke filler fully into the choke groove. Then, flatten the plastic mounting studs with a warm soldering iron to hold the filler in place.

With the outer-door casting removed, access is also available to the *latch-bracket* assembly. Although the adjustment procedure to follow pertains to most commercial *Litton* models, the process may be adapted, to some degree, to other similar latch arrangements. Locate the lock nut and allen bolt at the top and bottom of the latch-bracket assembly inside the door. Use a ½-inch open end wrench to loosen each lock nut. As demonstrated in Figure 15-17, insert an allen wrench into the latch-adjustment bolt and adjust the door by turning the allen wrench counter-clockwise to draw the latch-hook assembly back and thus tighten the door's fit against the cavity facing. Or rotate the allen wrench clockwise to slacken the fit. DO NOT OVER-TIGHTEN THE LATCH-ADJUSTMENT BOLTS—the mounting studs are spot-welded to the inner-door weldment, and will snap off if the adjustment bolts are over-tightened. The door latch is properly adjusted when the door latch hooks seat completely within the latch strike, achieving maximum actuation of

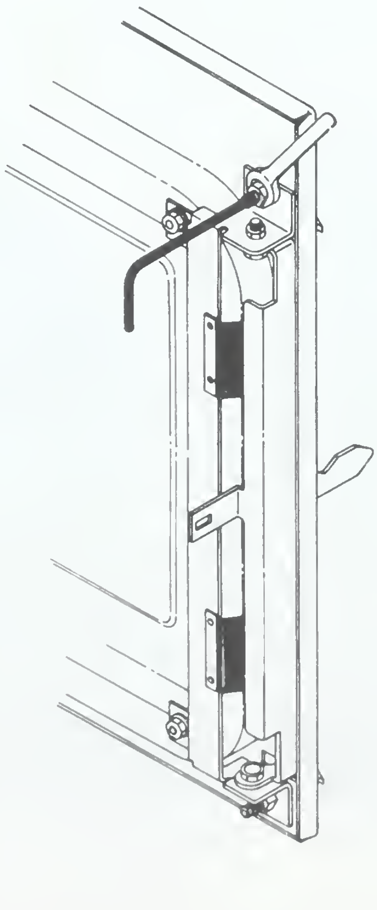


Figure 15-17 Adjusting a latch bracket assembly. (Illustration taken from service literature copyrighted 1985 by Litton Microwave Cooking Products. Used by permission.)

the switches without having to give the door an added push. Further, the door should be adjusted so that the latch hooks seat snugly against the latch strike surface. That is, so there is no front-to-back play between the latch hooks and the strike surface when the door is fully closed. If any lateral movement of the door hooks is necessary for proper switch activation, loosen the door-hinge bolts and move the entire door assembly as needed to achieve the optimum latch hook-to-interlock switch engagement.

When reassembling the door it is important that all parts be reinstalled or replaced in their original location, position, and relative orientation. It is imperative that the flanged retainer nuts not be over-tightened. Over-tightening these nuts will pull cute, but unacceptable "dimples" in the seal plate facing, necessitating its untimely replacement. As shown in Figure 15-18, snug down the nuts evenly, in a staggered sequence to avoid warping the inner door and possibly creating a hazardous—and expensive—microwave leak.

At times, certain areas of the seal plate will present a stubborn problem with excessive RF emissions. In these cases, the seal plate can be "custom fit", as it were, by the following procedure: While monitoring the area with an approved RF leakage meter, as shown in Figure 15-19, adjust the fit by slightly tightening or loosening the retainer nuts. Perform the adjustment so as to obtain the minimum amount of RF leakage (within acceptable limits), while maintaining the proper door closure and latching action.

Install the outer door by positioning it on the inner door, then pressing in at each corner until it snaps into place. Affix the handle and tighten it well. As a matter of routine, regardless of the nature of the service, any service on a commercial *Litton* should always include retightening the handle.

15.10.2 *Litton*-Made *Kenmore* Doors

These doors are disassembled by removing three screws along the bottom edge, plus

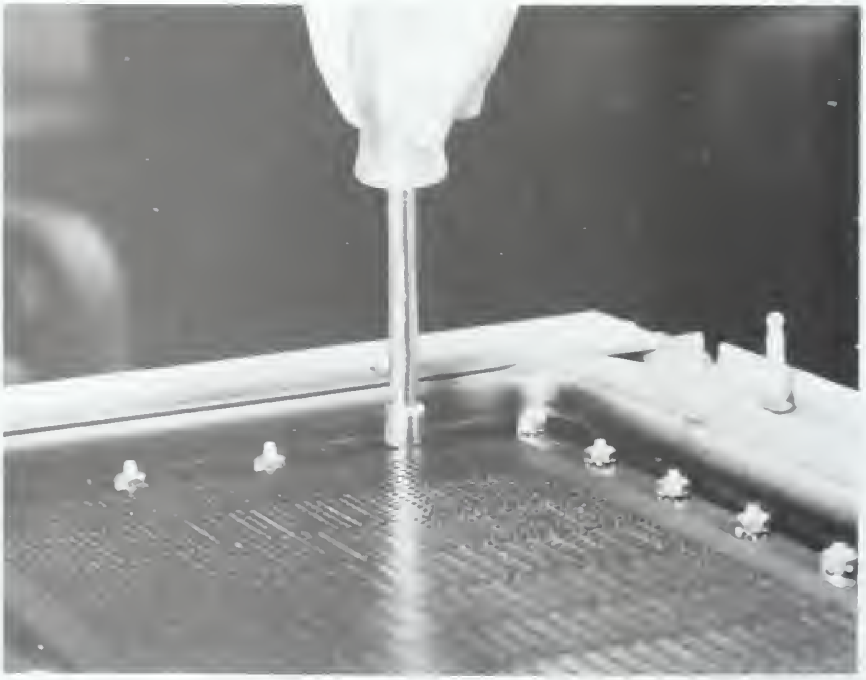


Figure 15-18 Do not over-tighten retainer nuts.

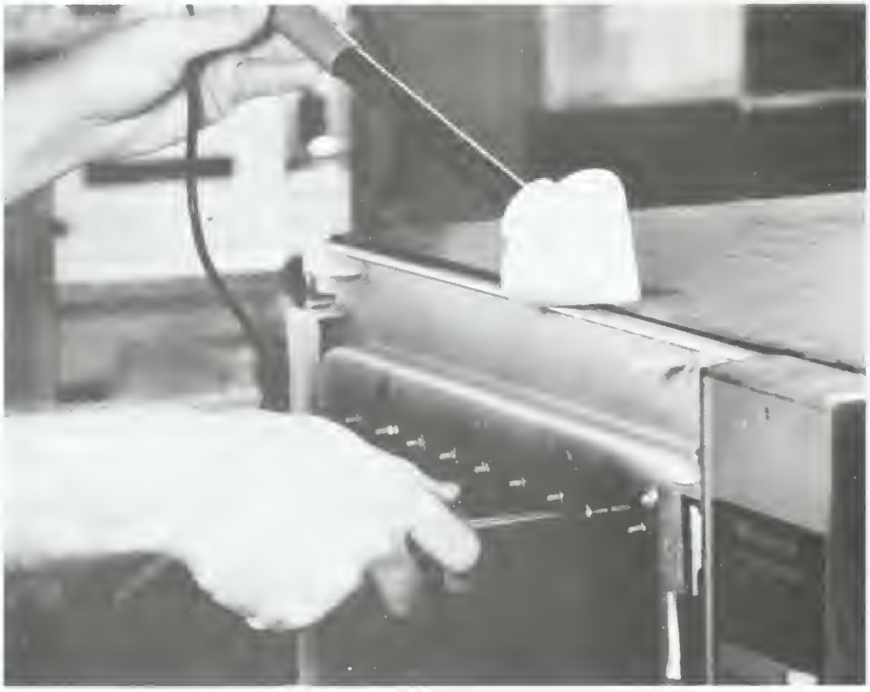


Figure 15-19 Adjust retainer nuts to minimize leakage.

the allen screw in the handle. Then, pull the bottom out slightly and lift up and remove the outer-door assembly.

Magic-Chef (1987-88 model) Doors

Along the lower front portion of the door there is a decorative woodgrain insert as shown in Figure 15-20. This insert must be pried up and removed (usually requiring its replacement) in order to access the screws for disassembly.

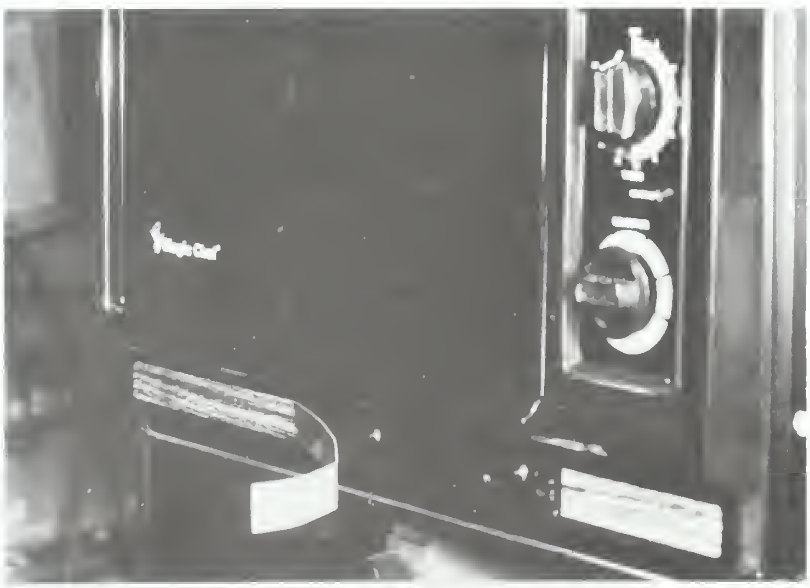


Figure 15-20 Remove insert to access retainer screws.

Post-Repair Leakage Check

Finally, as must be done after all door repairs or adjustments, the door must be checked with an approved and annually calibrated RF leakage measuring instrument as outlined in *Section 15.7.* This requirement is to ensure that the unit does not emit RF leakage in excess of 5 mw/cm^2 at 5 cm. (normal adjustments and servicing should limit the leakage to less than 1 mw/cm^2), and to verify compliance with the federal performance standards of the Department of Health and Human Services (DHHS).

Cooling and Energy Dispersion: Checks and Failures

chapter 16

16.1 INTRODUCTION

As discussed in *Chapter Eleven,* the cooling systems in microwave ovens serve not only to cool the magnetron, but also to produce a needed circulation of air for moisture removal, and in many models, to provide the turning power for the stirrer blade or antenna. Thus, a malfunctioning or failing blower system can engender a number of different symptoms. Not necessarily in order of their prevalence, the following are a few common symptoms.

16.2 SYMPTOMS OF BLOWER SYSTEM-RELATED TROUBLES

1. The oven is not cooking at full power although set on "high."

In this case, due to a problem in the cooling system the magnetron is overheating. When the magnetron *thermal protector* reaches its trip temperature, the thermal protector opens its contacts and thus opens the circuit to the primary of the high voltage transformer. (The effects of a tripped thermal protector vary with different makes and models, depending on the circuit configuration.) With no primary voltage, the magnetron ceases oscillation and thus begins to cool down. When the magnetron tube cools sufficiently, the thermal protector resets, primary voltage is once again applied to the transformer, and the magnetron goes back into oscillation—only to reach an overheated condition again. Hence, the magnetron cycles, although the controller is actually set on full power.

2. The oven is not cooking evenly, or its output seems weak, or both.

As a consequence of inadequate air circulation, the air-powered stirrer blade or antenna has stopped rotating; thus there is an inefficient distribution of energy, resulting in the hot and cold spots and weak output.

3. There is an abnormal buildup of condensation on the inside of the oven

door. Moisture may become visible even behind the timer faceplate or display lens.

A new owner of a microwave oven may give no heed to the absence of the "whir" of the blower. Unaware of a malfunction, the new owner may continue under these adverse conditions until either the magnetron *thermal* fuse opens and the oven goes dead, or the cycling condition described above precipitates an inquiry.

4. The control panel goes dead on an *Amana* RR9T, RR9TA, RR10, RR10A, or other similarly designed models.

Perceptive troubleshooting reveals the magnetron thermal fuse to be open and the temporary connection of a jumper wire across it causes the control module to "beep" back to life. With the jumper still in place, the oven is briefly tested and everything appears to operate normally, including the blower motor. Do not be fooled. A thermal fuse does not open without reason. Either the air ducting is out of place or, more likely, the blower motor is intermittently stopping. This is usually the result of a faulty terminal-to-winding connection within the motor and, while it can be repaired, the most practical course is to replace the blower motor.

5. The oven operates normally, then shuts down and will not come back on for 15 to 20 minutes (the period of inoperation depends on the ambient conditions).

The first and most obvious cause is a defective blower motor. The magnetron is overheating and the thermal protector is cycling the oven in and out of operation accordingly. However, what if this condition is observed while the blower system appears to be operating normally? Several factors must be considered: 1) Low voltage will cause the magnetron to run abnormally hot. 2) Either the air circulation is being impeded or the oven is situated so preheated air (either from the oven's own exhaust or from another source) is being drawn in through the fresh air intake vents. And 3), the blower wheel or fan blade is slipping on the motor shaft, and thus never achieving full speed.

All three conditions can be corrected. The first suggests a parley with the local power company, or employing a voltage booster. The second condition will be rectified with adequate cleaning, or relocating the unit so as to improve the air circulation. The third involves replacing or regluing the blade or wheel, depending on the circumstances. The procedure is as follows:

Unplug the oven and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S), then determine if the blade or wheel is loose. Hold the motor shaft stationary by gripping it with a pair of pliers, then try to rotate the blade or wheel by hand. If the blade or wheel is able to slip on the shaft, it is loose. Replace the wheel or blade, or if the hub is not wallowed out too badly, it may be glued to the shaft. Before applying the glue, rough-up the shaft with sandpaper or a file for a good bonding surface. Place a drop of suitable adhesive (Eastman 910[R], Locktite Super-Bonder[R], 3M CA-4[R], or an equivalent) on the inside of the hub and slip it on the shaft. Let the glue set, then test the unit for proper operation.

6. In the convection mode the oven never achieves the proper cavity temperature, although there does seem to be heat.

Suspect a broken or slipping belt, or a defective convection fan motor.

16.3 BLOWER MOTOR TEST

When the blower or convection fan motor is suspected, perform the following tests:

1. Unplug the oven, remove the oven wrap, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. Manually check the blower wheel or blade to make sure it is not binding or frozen.

3. Isolate the motor winding from the surrounding circuitry by carefully removing the harness leads from one (either) terminal. Be careful! While gently removing the harness lead connector, support the coil terminal to avoid breaking the housing and possibly the tiny internal coil wire.

4. Set the ohmmeter on an appropriate resistance scale and measure across the coil of the blower motor. While normal readings will vary with motor brands, an indication of approximately 8 to 13 ohms is typical, and some may read from about 30 to 40 ohms. However, a reading of infinity (or no meter movement) indicates an open winding or open thermal fuse within the winding, in which case the motor must be replaced.

> NOTE: Some earlier *Amana* commercial units were designed with a thermal fuse embedded within the blower motor windings which, if opened due to an overheating or overcurrent condition, will render the entire oven inoperative and a restaurant owner frantic. To restore operation, either the blower motor assembly must be replaced or, if the motor windings are intact and if the source of the abnormal condition has been determined and corrected, then, strictly in an emergency situation and only as a temporary user-soothing measure, the thermal fuse can be replaced. First, carefully peel away the necessary layers of wrapping to gain access to the open fuse. Then extract the fuse by cutting its leads, leaving enough of each original splice for soldering. The temporary replacement thermal fuse must be within an acceptable temperature range of the original fuse (determined by specifications imprinted on the fuse body—see *Section 14.5.1*). Use a low wattage soldering iron to tack in the replacement fuse. Be sure to use appropriate heat-sinking measures as outlined in *Section 14.5.1*. Check the unit for proper operation. This temporary measure should promptly be made permanent by replacing the entire blower assembly as soon as a replacement can be obtained.

16.3.1 Operational Blower Motor Test

1. After unplugging the oven and DISCHARGING THE CAPACITOR(S), disconnect the leads from one of the high-voltage transformer primary terminals. This ensures that no high voltage will be generated during this test. Also, if necessary, defeat the wrapper interlock switch. BE CAREFUL—line voltage can be hazardous to your health.

2. Attach a meter capable of measuring the applicable line voltage AC across the input leads to the blower motor.

3. Apply power to the oven and initiate a function which normally energizes the blower motor. For example, in some ovens, simply opening the oven door will energize the blower. In others models, the motor runs only during a cook cycle.

4. The meter should indicate approximately 120 volts AC or line voltage. If the proper voltage is present and the motor does not operate, replace the motor. If the appropriate voltage is not indicated, either the oven is not in a mode in which the blower normally operates, or the corresponding control circuit or associated wiring is at fault.

16.3.2 An Alternate Test

Unplug the oven and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S). Remove all the leads from the blower terminals, then attach an AC test cord (cheater cord) to the blower terminals. Plug in the test cord, and check the operation of the blower motor.

16.4 ENERGY DISTRIBUTIONS SYSTEMS—CHECKS AND FAILURES

The relative evenness of an oven's cooking pattern can be determined by the following microwave heat distribution check. This involves placing equal amounts of water at certain points inside the oven cavity. After a period of time, cooking at full power, the individual temperature rises are measured and compared. For this test, metal racks should be removed and the glass or ceramic cooking tray should be in place.

16.4.1 Microwave Heat Distribution Test

1. Prepare 5 suitable non-metallic beakers and measure out 250 milliliters (1 cup) of tap water into each beaker.

2. Measure and record the initial water temperature of each beaker.

3. Place one beaker at each corner of the cooking shelf, evenly spaced from the oven walls. Place the remaining container in the center of the cooking shelf.

4. Heat the water at full power for 2 minutes, then remeasure the temperature of the water in each beaker and record the amount.

5. Calculate the temperature rise for each container by subtracting the starting temperature from the finishing temperature. Then, using the least (minimum) and the greatest (maximum) of the 5 temperature rise amounts, compute the following formula to determine the heat distribution rate: $T1$ = minimum temperature rise, $T2$ = maximum temperature rise.

$$\text{HEAT DISTRIBUTION RATE} = \frac{T1}{T2} \times 100\ (\%)$$

The result should exceed 70 percent. If, for example, the water temperature of the beaker in the left rear corner rose the least of all, at a rise of 8°. Then $T1 = 8°$. Perhaps the beaker in the center showed greatest temperature rise, say 10°. Therefore $T2 = 10$.

The formula would then work out as follows:

$$\text{HEAT DISTRIBUTION RATE} = \frac{8}{10} \times 100\ (\%)$$

$$\text{Thus:} \quad 0.8 \times 100 = 80\%$$

80% exceeds the 70% criteria for acceptable heat distribution, so the stirrer system is operating normally in this case. If abnormal results are obtained, the stirrer system should be checked. Indeed, whether air-, belt-, or motor-driven, and whether a reflector or antenna, ***the rotation of the energy dispersion system should be routinely verified during the course of all service, regardless of the nature of the problem.***

16.4.2 Verifying Stirrer or Antenna Rotation

Depending on the model, there are at least four different ways in which the rotation of the stirrer or antenna can be visually verified without removing the outer case: 1) With a sizable water load inside the cavity and the oven set at its lowest power setting, operate the oven and, perhaps with the aid of a flashlight and wisely wearing the special protective glasses described in *Section 5.4,* peer briefly through the door to observe the rotating silhouette of the stirrer blade or antenna through the translucent white plastic cover. 2) Place a water load in the oven and begin a cook cycle. After about 30 seconds, open the door and quickly observe (through louvers or other openings in the stirrer cover) the rotation of the blade or antenna as it coasts

to a stop. 3) If neither of the aforementioned procedures are workable, try the following: With motor- or belt-driven systems, simply remove the stirrer cover (or grease shield) and operate the oven to observe the turning blade or antenna. It should be noted that air-driven systems usually require the stirrer shield to be in place to achieve the necessary air ducting for the blade or antenna to turn. Remove the stirrer shield and make a reference mark on the blade or antenna. Reinstall the stirrer shield and operate the oven. After about 30 seconds, stop the oven and unsecure the stirrer shield to the extent that the reference mark is visible. If it has moved, the blade or antenna must have also moved.

(NOTE: In some systems the outer case (or side panel of an *Amana*) provides an essential air duct closure which also must be installed for proper operation. If the oven must be operated with the outer cover or side panel removed, a cardboard closure can be made to temporarily substitute for the cover. This will ensure rotation of the blade or antenna and thus avoid shelf damage, arcing, and even eventual magnetron damage.)

Finally, but not conclusively, put a microwave test light (described in *Section 5.4*) in the oven cavity and put the oven into a full power cook cycle. Usually, but not always, the rotation of the blade or antenna is confirmed by the blinking of the test light.

On occasions when the outer case has been removed, stirrer or antenna rotation is confirmed much more easily. Usually, small holes in the stirrer compartment provide an adequate view of the turning blades.

Keep in mind too, that some energy distribution systems are only as good as their designs. A cooking pattern judged unacceptable in one brand may be normal, such as it is, in another. Remember too, that a weak magnetron, or one oscillating off-frequency, can also produce unsatisfactory heat distribution.

16.5 STIRRER OR ANTENNA MAINTENANCE—AIR-DRIVEN

If the routine visual verification reveals a stalled stirrer blade or antenna, check the following in air-driven systems:

1. After unplugging the oven and discharging the capacitor, ensure that all air ducts and closures are properly in place. On domestic *Amana* models, particularly, routinely inspect the air gasket material (that extends laterally across the top of the oven) for deterioration or displacement. This foam gasket serves to direct and confine the air flow to the antenna compartment, and is therefore vital to antenna rotation. Replace the foam material if necessary.

2. Also, as a matter of course on the same models, check the grease shield for warpage. Time and hot steam eventually cause the center of the grease shield to sag, and, in the case of *"Rotowave"* systems, the grease shield's essential ducting effect is lost. In the earlier stirrer systems as the center sags, the back of the grease shield draws forward and soon obstructs the rotation of the blades.

3. Remove the stirrer shield and manually rotate the blades to assure free movement. Inspect the compartment for accumulated grease or other gummy deposits.

16.6 STIRRER OR ANTENNA MAINTENANCE—MOTOR-DRIVEN

If the blades are not rotating and respective drive belts, pulleys, and gears are intact, in place, and not slipping or binding, check the motor as follows:

1. Unplug the oven, remove the outer case, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S) by shorting the terminals together and, to ground, use an insulated screwdriver.

2. Electrically isolate the motor by disconnecting the harness leads from one of its terminals.

3. Set the ohmmeter to an appropriate resistance scale and measure accross the motor terminals. A typical resistance value of a stirrer motor winding is approximately 2300 ohms.

16.6.1 An Operational Check

1. Unplug the oven, remove the outer case, and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. Connect a meter capable of measuring 120 volts AC (or the respective line voltage) across the input leads to the stirrer motor.

3. Apply power to the oven and initiate an operation that normally energizes the stirrer system. In some models, simply opening the door activates the stirrer motor. In others, the oven must be put into a cook cycle. In the latter case, one of the primary leads to the high-voltage transformer should first be disconnected before the oven is plugged back in, so that no high voltage is generated during this test. But be careful—line voltage is also dangerous.

4. If the appropriate line voltage is indicated on the meter, but the motor does not rotate, manually verify that the stirrer blade or antenna is not binding. If the blades turn freely, then the motor is defective and must be replaced. If the necessary line voltage is not present, check the corresponding control circuitry and wiring for other possible causes.

16.6.2 An Alternate Test

Unplug the oven and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S). Remove the harness leads from both motor terminals, then attach an AC test cord (cheater cord) to the empty terminals. Plug in the test cord, and evaluate the operation of the stirrer or antenna drive motor.

16.6.3 Stirrer or Antenna Motor Replacement Considerations

While the disassembly procedures vary considerably from one model to the next, two important factors are common to most: 1) The wire mesh RF gasket (similar to the magnetron RF gasket) that seals the union between the motor housing and the cavity must be properly in place and the motor mounting screws tightened securely. Often a new gasket is included with the replacement motor. 2) To meet federal guidelines and to ensure that the repair area does not emit excess microwave leakage, an RF leakage check is required after all repairs of this nature. Perform the leakage test as outlined in *Section 15.7.*

16.7 ROTATION SYSTEMS—CHECKS AND FAILURES

These systems use a turntable motor to turn a circular tray on which the food is placed. Thus the food rotates through the field of microwave energy. The turntable motor is mounted to the underside of the cavity floor and linked through the floor to a hard fiber-like coupling. There is a problem that occurs with these couplings that renders them burned and melted. The condition is apparently the result of accumulated grease or food deposits burning, then carbonizing and arcing, and conse-

quently breaking down the hard fiber-like plastic material of the coupling. The intense heat generated by the arcing and burning may also damage plastic gears in the motor assembly and cause the internal gear lubricant to loose its lubricative qualities. Therefore, in addition to replacing the mutilated coupling, the motor assembly should also be scrutinized very carefully for heat damage. If the motor is unusually noisy, or rotates erratically, the assembly is probably damaged and should be replaced. When this not-uncommon coupling-breakdown condition is encountered, the repair must include meticulous cleaning of the affected area to remove all traces of carbon, grease, and other contaminants. Also, the customer may be tactfully advised that regular and thorough cleaning after each use with mild, sudsy water will help to prevent the condition from reoccurring.

If the turntable (or carousel) fails to rotate at all, the motor can be checked in the same manner as outlined for the stirrer motor. The only difference is the resistance value of the motor winding, which for a turntable motor a normal reading can range from about 30 ohms on some models to around 2000 ohms on others. A reading of infinity indicates that the coil is open and the motor must be replaced.

16.8 STIRRER AND WAVEGUIDE COVERS, GREASE AND SPLATTER SHIELDS—PROBLEMS

Residual grease, crumbs, and other food debris are usually among the fomenters of a condition, similar to the coupling breakdown mentioned above, which involves the various plastic and fiber covers that shroud the stirrer or antenna compartment on some models, and the waveguide opening in others. As mentioned in *Section 11.6,* the waveguide cover is made of a material that seems to be, under certain circumstances, particularly susceptible to arcing. If accumulated grease, trapped food particles, or other food contamination is heated over and over again, eventually it reaches the point of carbonizing. Consequently, the affected surface of the brittle fiber-like waveguide cover breaks down and begins to arc and burn. Visually, the damage may be quite obvious as shown in Figure 16-1. Or, the arc may have occurred on the concealed upper surface, in which case removing the waveguide

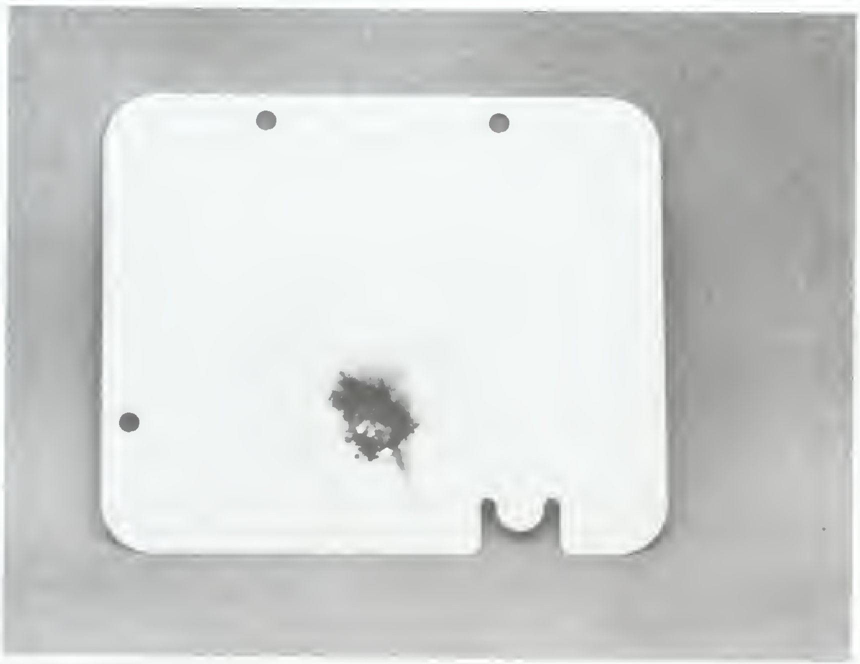


Figure 16-1 Results of arcing.

cover will reveal the burned spot—albeit only the size of a pencil point in some cases—where the arc materialized. The waveguide cover must be replaced. First, however, the accessible interior walls of the waveguide opening, the retainer-tab notches and the surrounding adjacent surfaces—*with their sharp edges*—must be completely cleaned (and sanded in some instances) of all carbon traces, grease, crumbs, and other foreign matter. If sanding is necessary, even if the sanded surface is to be concealed by the waveguide cover, the bare metal should be touched up with the appropriate cavity paint. If the mounting tabs are bent down or up, they should be formed back to a level and uniform position relative to the waveguide cover they support.

The condition just described may also occur, although not as often, in models with stirrer covers. For the same reasons just mentioned, the mounting flange of the stirrer support bar in certain *Litton* models will break down, arc, and burn. In many cases the stirrer cover is also damaged. However, an improved mounting arrangement, which now comes as a standard replacement part, has virtually eliminated that particular problem.

Also, as previously considered, stirrer cover warping and sagging presents air flow and binding problems that retard, impede, or halt the rotation of the stirrer blade or antenna.

16.9 INTERRELATED FAILURES

Given the great interdependency that exists between one integral section, with its correlated components, and another equally elemental constituent, it becomes quite evident that seemingly unrelated problems and failures would, in fact, be indivisibly interrelated and reciprocative. Thus the deliberate parallelism and apparent redundancy in the preceding failure descriptions and explanations. Indeed, in a microwave oven, it is precisely these complex complementary component relationships that oblige the servicer to acquire and utilize the fine *art of troubleshooting*.

Troubleshooting by Symptom, Make, and Model

Part 5

Part 5, consisting of *Chapters Seventeen* and *Eighteen*, presents a philosophy and a guide to troubleshooting. This is the product of many years of compiling notes and gathering data on problems, symptoms, and solutions as they apply or are unique to all, some, or only one make or model. For example, a symptom of *uneven heating* is most likely caused by a warped grease shield in an *Amana*, a broken stirrer belt in a *Magic Chef*, and misaligned stirrer shaft entrance holes in a *Thermador*. Part 5 begins with brief discussion on the art of troubleshooting itself. The process of analyzing and interpreting given factors through tests and other means, keeping an open mind, eye, and ear, in order to locate and eliminate a source of trouble.

The Art of Common Sense Troubleshooting

chapter 17

17.1 INTRODUCTION

Effective troubleshooting begins with a thorough understanding of the specific equipment to be maintained. Hopefully, this has been achieved to a reasonable degree. By combining the following basic troubleshooting principles with the knowledge garnered from the preceding chapters, the ability to track down a problem in a microwave oven will become almost intuitive, second nature, artful.

Common sense troubleshooting involves a *systematic* approach and the efficient use of applicable methods. The objective is to *eliminate the cause*, and not just the symptom. While replacing defective parts or making necessary adjustments requires a significant degree of skill and dexterity, qualities which are soon acquired from experience, the effective isolation of the actual source of a problem requires a somewhat greater skill, mindful alertness, and a healthy dose of common sense.

17.2 PRACTICAL WISDOM IN TROUBLESHOOTING

Tracking down trouble in a microwave oven can be likened to the way a detective investigates a case: First, the sleuth gathers information through tactful, yet probing interrogations, to ascertain pertinent details from those involved. In the same way, ascertaining accurate and detailed symptoms, along with any coincidental peculiarities, from the owner or operator of a microwave oven, is vital to starting on the right track. Next, with keen awareness, discernment, and ingenuity, the detective searches for clues. As facts are revealed and evidence is evaluated, irrelevant and misleading indications are noted and put aside for the time, while the more solid and pertinent clues are pursued. Likewise, the microwave oven servicer must use practical wisdom in troubleshooting. Two fundamental precepts come to the foreground in this regard: 1) Be observant and alert to the obvious. The majority of problems are conspicuous and readily detectable by one or more of the senses. And, 2) Keep

an open mind. While the technician must always have clearly in mind the precise areas where the trouble *can* exist, he or she must not allow preconceived conclusions, or indeterminate, deceptive, or abstract findings, to *blind* himself or herself to the real problem.

In the mind of the detective, progressive conclusions are being drawn. The effectiveness of the investigation is further enhanced because the experienced detective also knows that some suspects are more apt to be guilty than others. And, that certain crimes are usually committed by the same suspect. So, through a process of logical deductions based on reasonable likelihood, the clever investigator systematically narrows down the possibilities by eliminating all of the least likely suspects until only the guilty party remains.

Now apply this to a microwave oven. For example, say the complaint is that the door is hard to open. Is there any reason to believe that the magnetron tube could be the cause of the binding door? No, of course not. In fact, the entire high voltage system, the cooling and stirrer system, and the electronic control section, could all be immediately eliminated as suspects. Logically, the latch mechanism would be the most likely area to investigate. But which part of the latch mechanism? First, divide the workings into sections of equal likelihood—the latch hooks, the door itself, and the latch-strikes (on which the interlock switches are mounted). Perhaps, in this example, experience has shown that the plastic latch-strikes tend to break in these particular models. That being the case, the next step is obvious. Otherwise, evaluate the adjustment, alignment, and integrity of each area. Eliminate those areas which are merely symptomatic of the condition, and forthrightly isolate the cause of the bind.

In time, knowledge gained from experience will yield the ability to quickly recognize certain problems simply by associating the symptom with the model or brand. There will, however, be unusual symptoms and unfamiliar models, and thus countless occasions when this "divide and conquer" technique will prove invaluable.

17.2.1 Sample Troubles

To further illustrate this method, in the first of two examples, notice how it is applied in the simplified microwave oven circuit of Figure 17–1.

TROUBLE #1

The customer's complaint is a traditional one—the oven is not heating. Before removing the cover, conduct a primary operational and observational test using the microwave test light (*Section 5.4*). This broad check not only confirms the complaint, but also provides some additional preliminary data. During that initial test the blower motor, the stirrer motor, and the timer motor appear to function normally. But the cavity light does not come on. Although experience has shown that this type of bulb is prone to burn out, its failure to light is a factor to consider. Clearly, though, there *is* voltage available at points "E" and "F", and therefore the circuits (or current paths) must be complete from points "G" to "E" and from points "F" to "H", as indicated by the arrows in Figure 17–1. So, without even removing the cover, the fuse, the primary interlock switch, the timer motor and contacts, the stirrer motor, and the blower motor have already been eliminated as suspects. In addition to that, by listening very carefully while opening the door, three audible clicks were heard, and then heard again when the door was closed. Although the clicks are not conclusive, they do indicate that, in all probability, the switches can also be eliminated as suspects—at least for the time being.

Now, having unplugged the oven, removed the cover, and discharged the high-voltage capacitor, observe. Often an incisive visual inspection at this point reveals an

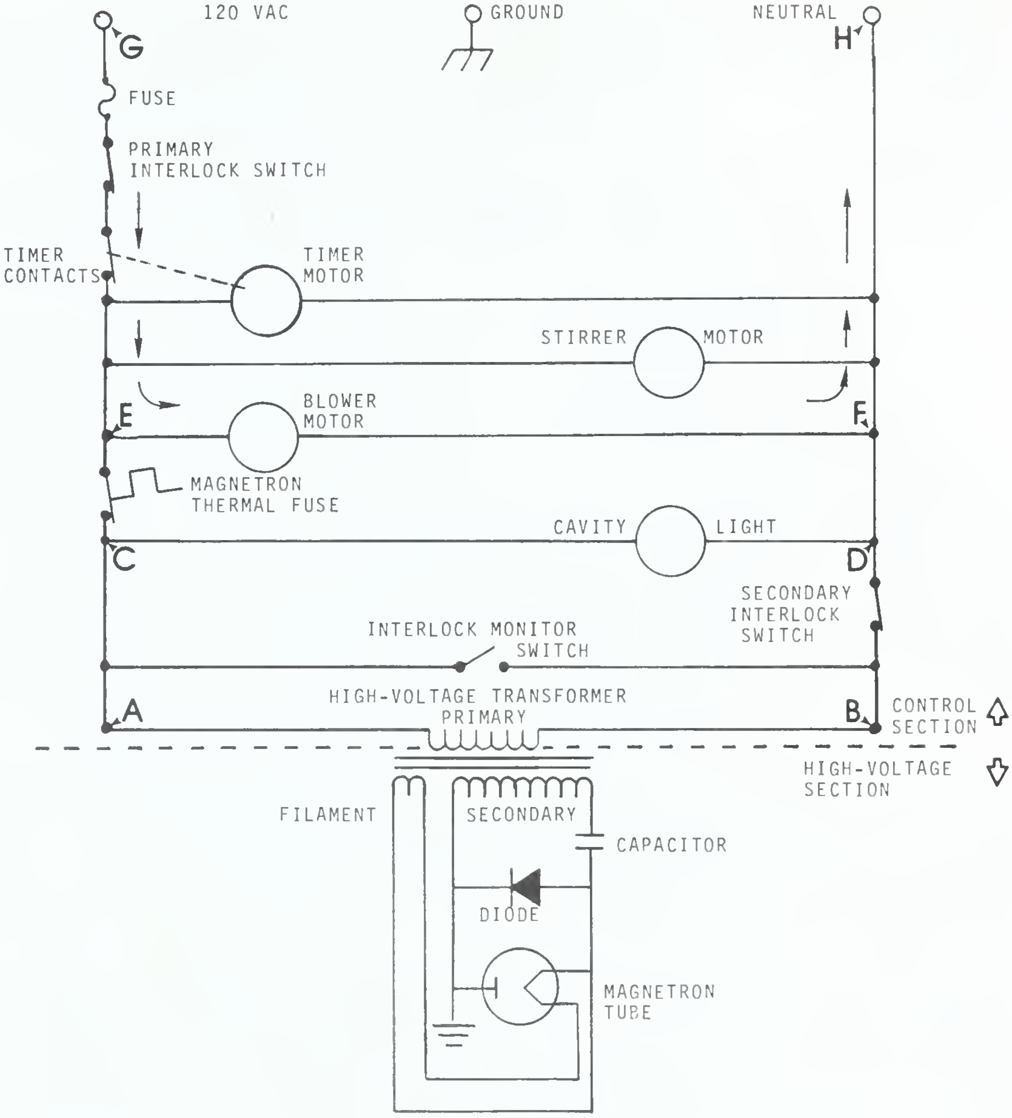


Figure 17-1 Sample circuit.

important or conclusive clue. However, in this illustration the perusal reveals no abnormalities. So, the next logical step is to determine whether the trouble exists in the high voltage section or the control section. This is done by dividing the overall system across the middle as indicated by the dashed line. The dividing point is the primary winding of the high-voltage transformer. This effectively isolates the trouble to the high-voltage section or the control section.

Observing all the necessary safety precautions for operational ("live") testing, attach one meter lead to point "A" and the other to point "B". To obtain an accurate measurement across the transformer primary, the existing harness leads must remain connected. Set the meter to a scale capable of reading 120 volts AC, plug the oven in, initiate a cook cycle and observe the meter. If the meter indicates 120 volts AC, the control section is functioning normally and the trouble must, therefore, exist in the high-voltage section. If, on the other hand, the meter shows a reading of zero volts, the problem lies somewhere in the control section.

In this sample case the meter shows a reading of zero volts, indicating that no primary voltage is being supplied. Now, while a problem may yet exist in the high-

voltage section, the immediate and predominant trouble must be in the control section. Since it is known that the control circuit is intact up to points "E" and "F", the only questionable areas remaining are from points "E" to "A", and from points "F" to "B". Therefore, the suspects are narrowed down to the magnetron thermal fuse, the secondary interlock switch, and the associated wiring.

NOTE: Loose or disconnected wires are more likely to be encountered in ovens that are relatively new (less than 6 to 8 months old).

Remembering the three audible clicks of the interlock switches, the secondary interlock switch becomes a secondary suspect. This leaves the thermal fuse as the primary suspect. With the oven again unplugged, and the capacitor discharged, a continuity check across the terminals of the magnetron thermal fuse (points "E" to "C") shows a puzzling reading of about 10 ohms. Does this mean that the thermal fuse—the primary suspect—is not the problem after all? No. It means that the thermal fuse was not properly isolated from the surrounding circuit before being tested. The meter was reading through the cavity light filament (about 2 ohms) to point "D", up to point "F", and back through the winding of the blower motor (about 8 ohms) to point "E" (a total of 10 ohms). After removing the harness leads from one of its terminals, a continuity check across the thermal fuse shows no reading (infinity). Thus, the thermal fuse is, in fact, open. However, that leaves a question: Why did the thermal fuse open if the blower motor is functioning normally?

The question is answered through a telephone call to the customer which reveals that the oven was just recently mounted into a cabinet with what proved to be inadequate ventilation. So, after replacing the thermal fuse, a final checkout confirms the proper operation of the oven.

TROUBLE #2

In this second example everything appears to operate normally, except that the oven is not heating. This time, during the preliminary observations and precautions, it was noticed that the capacitor yielded an unusually fearsome spark when discharged. While this may be normal and insignificant, it is worth noting. The dynamic discharge suggests at least three factors, although none of which are conclusive: 1) High voltage is being generated, thus the control section must be providing primary voltage. 2) Perhaps the capacitor is storing an abnormally high charge because the magnetron is not conducting properly for some reason. And, 3) The capacitor's ability to hold a charge is a good indication that it is not defective.

Subsequently, a voltmeter capable of reading 120 volts AC is attached across the primary winding, points "A" to "B" of Figure 17-1 (the harness leads remain connected). The oven is put into a cook cycle and, sure enough, the meter reads 120 volts AC, confirming the presence of primary voltage. Logically then, the trouble is not in the control section. That leaves the high-voltage components as the most likely suspects.

Once again the oven is unplugged and the capacitor discharged. The *diode* appears normal and there is no hint of the pungent burning smell that usually accompanies its failure, but it is a likely suspect and it tests quickly and easily as outlined in *Section 12.10*. The diode is checked, and is found to be normal. While a shorted *capacitor* will normally blow the line fuse, an open *capacitor* will produce the existing symptom. However, with that notable discharge in mind, the capacitor and the transformer are reduced, for the time being, to secondary suspects. The magnetron now becomes the prime suspect.

Following the procedure outlined in *Section 12.5*, the magnetron is quickly

checked and, to that extent, it checks normal. Reverting to the less likely suspects before advancing to a "live" test, resistance checks are performed on the high-voltage transformer and capacitor as outlined in *Sections 12.8* and *12.9* respectively. The tests prove normal in both cases.

The final and near-conclusive test is to check for filament voltage. This involves a very important preliminary step, as indicated in the procedure at *Section 12.2.1, step 4:* The HIGH VOLTAGE LEAD MUST BE COMPLETELY REMOVED. Although removing the high-voltage lead will prevent high voltage from being applied to the magnetron, HIGH VOLTAGE WILL BE PRESENT AT THE TRANSFORMER SECONDARY TAP. So, using the appropriate procedure and precautions, the test discloses a lack of filament voltage. The transformer primary and secondary windings were checked previously, so the possibilities are narrowed to the associated wiring and terminal connections.

As a rule, a defective *high* voltage connection will be quite obvious by the sparking, burning, and other visual indications. However, the comparatively tiny filament voltage (typically 3 volts AC) is easily impeded and may leave little in the way of any visual indications of that fact. With that in mind, the filament connectors are disconnected from the magnetron terminals and closely examined. The inspection reveals an improperly crimped connector. The insulation had not been properly stripped away and was thus pinched between the wire and the connector. With a new connector *properly* crimped in place and all wires securely reconnected, the oven cooks—and the cook is overjoyed.

17.2.2 A Final Note on Troubleshooting

The preceding discussion has basically illustrated a proven technique for tracking down trouble in a microwave oven using the schematic, resistance checks, and other audio and visual indicators. Remember, all troubleshooting must be governed by a good measure of common sense. Therefore, if desired test points are not accessible, then the basic procedure must be altered as necessary, perhaps using test points that are the equivalent electrically, but more easily accessible. While most manufacturers supply an oven schematic, either on the underside of the outer cover, or elsewhere, the lack of a schematic need not cripple the troubleshooting effort. Again, using common sense, critical observation, systematic resistance checks, and by logically analyzing the symptoms (i.e., what could and could not cause the symptoms noted), the trouble can, nonetheless, be efficiently tracked down in a reasonable amount of time.

17.3 GUILT BY ASSOCIATION

Summarizing and supplementing the many descriptions of typical troubles that have been interspersed throughout the preceding pages, the following collection of common and unique problems will furnish the technician with a broad cross section of microwave oven service experience. This consolidated source will reinforce the technician's ability to recognize many common types of failures by associating the symptoms with the brand, and will prove a valuable troubleshooting reference in the future.

The section begins with some general symptoms that are common to most brands, and progresses into problems that are more unique to specific manufacturers. The symptoms are listed alphabetically, and are generally termed as they are typically expressed by the customer. Also, each symptom is accompanied by the most likely cause or causes, possible preventative procedures, and the appropriate corrective action.

Basic Common Problems

1. Arcing
   A. Arcing in the oven cavity:
      (1) Loose or displaced stirrer blade. Or, dirty worn or damaged (blistered, melted, or distorted) stirrer shaft or bushing.
      (2) Dirt and grease carbonize and cause arcing. Especially in models with fiber-like waveguide or stirrer covers.
      (3) No load or low load operation.
      (4) Voids in the shelf sealer allow grease to seep into cavity well, eventually resulting in carbonizing and arcing.
      (5) Improper placement of metal cooking racks, or metal utensils, which requires diplomatic customer education.
      (6) In all cases of arcing, the damaged area must be thoroughly cleaned of carbonized debris, rough edges, and appropriately refurbished.
   B. Arcing around the door:
      (1) Accumulated grease and crumbs trapped between the door and cavity facing, or in inaccessible areas inside the door, carbonize and cause arcing.
      (2) Horizontal sear marks on the plastic inner door generally indicate improper rack installation or use. Burn marks are also caused by metal utensils placed too close to the door. Tactfully advise the customer accordingly.
         (a) Small burn holes which result from arcing can be cleaned, smoothed, and covered with a clear plastic adhesive patch.
      (3) Worn or damaged seal plates can cause arcing and should be replaced.
      (4) A stalled stirrer blade will direct concentrated beams of energy to spots on the door, causing arcing, scorching, and shattered inner windows.
   C. Arcing in the high-voltage section:
      (May cause the electronic control panel to act erratically or reset due to electrical transients generated during the arcing.)
      (1) Inadequate spacing between high-voltage wires. Dress wires so as to maximize the spacing between wires, and between each wire and chassis ground.
      (2) Improper phasing of the high-voltage transformer. It is critical that the transformer primary be properly wired. The transformer filament leads must also be connected to the appropriate magnetron terminals. If the proper wiring for a particular model is not known, refer to the specific service manual for that model.
2. Bad odor in the cavity:
   A. Perhaps a potato or some popcorn overcooked and burned in the microwave oven. This generally results in an unpleasant "burned" odor inside the cavity for quite some time. The odor can be neutralized to some extent by filling a power test bowl with lemon juice mixed with a little water, then boil this concoction, until almost completely vaporized, several times each day for two days. Over-

night, place some used coffee grounds, suitably contained, in the oven cavity. The odor will usually subside soon after this process.

3. Blower is noisy:
   A. Blade or wheel loose on the shaft. Reglue or replace the slipping blade.
   B. Worn motor bearings.
   C. Warning label or instruction sticker of some sort loose and flapping.
4. Door handle is broken:
   A. While some handles do seem to break routinely, many times this is caused by a tight-fitting door or a worn latch mechanism. If excessive effort is required to open or close a door on which the handle has broken, appropriate adjustments or repairs should be made.
5. Fuse is blown—oven is "dead"
   A. If associated with opening or closing the door—or if the fuse appears to have blown violently—check the operation and timing sequence of the interlock-monitor system. It is recommended that all switches in the interlock loop be replaced when the fuse blows due to the action of the monitor switch.
   B. If the fuse opens during the cook cycle:
      (1) Check to see if the fuse is held tightly in fuse holder. Beads of solder protruding from the end cap indicate a defective fuse holder.
      (2) If the fuse's opening was accompanied by a low rumble, especially during a lower power setting (i.e., defrost), or at the conclusion of a cook cycle, suspect the triac.
      (3) If the fuse opens during the first 1 to 3 seconds (approximately) of the cook cycle, perhaps accompanied by a loud snap, check for a shorted capacitor.
      (4) When the fuse opens after the magnetron has gone into oscillation, usually from 30 seconds to several minutes into the cook cycle, the high-voltage transformer probably has a shorted winding. In most cases the transformer will be abnormally hot as a result of this condition.
      (5) Evidence of roaming roaches can explain intermittent fuse failures when no other reason seems apparent. The "well-done" creature in Figure 17–2 roamed a little too close to the high-voltage capacitor. The ensuing electrocution resulted in one less roach, a blown line fuse, and a shorted high-voltage diode.
      (6) Both marginally low or high line voltage and voltage surges can be the unapparent cause of a fuse failure.
6. [The oven] Goes "dead" (apparently) in mid-cycle. Restart, and everything works. Check the power plug for evidence of overheating, such as blistering or discoloration. If the plug is overheating, it is due to resistive heating caused by a faulty connection within the wall receptacle (or outlet). Advise the customer accordingly.
7. Heats intermittently:
   A. A *moding* magnetron will initially heat normally then, after a period of operation, will break down and lose oscillations completely. It may produce a pronounced low hum at this point. Such a

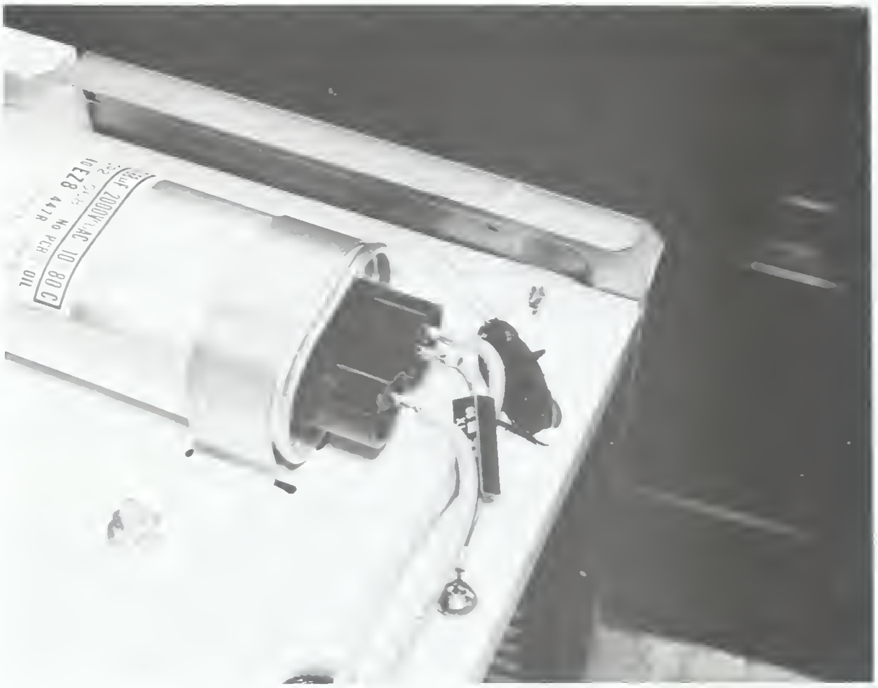


Figure 17-2 Roaming roach—deceased.

magnetron may show normal or slightly high plate current when in this moding condition.

B. Loose magnetron filament connectors.

C. Adjustment of the interlock switches marginal.

D. Check for loose switches or burned switch harness connectors. Also examine the latch assembly for binding or misadjustment.

E. Intermittent triac, or burned contacts on the cook relay.

F. Intermittent stirrer or antenna assembly.

8. Heats slowly:

(Also may include the symptom of heating some items normally, but others unsatisfactorily.)

A. Weak or moding magnetron. Plate current may be low—about ½ of normal.

B. Stalled stirrer blade or antenna.

C. Low line voltage—10 percent below normal can be critical.

D. Defect in the control section causing unwanted magnetron cycling.

E. Overheating condition causing the magnetron to cycle due to the cycling of the thermal protector.

F. Timing circuit or mechanism inaccurate—concluding the cook cycle too soon.

G. Accumulated grease under cavity shelf absorbing energy and robbing efficiency.

H. A magnetron oscillating off frequency will heat some items normally (i.e., water) while producing unsatisfactory results in other types of foods.

9. Heats unevenly—hot spots:

A. Stirrer or antenna not rotating in motor driven systems:

(1) A defective motor is often evidenced by notable grinding noise.
(2) Loose or broken belt.
(3) Blades obstructed by warped or broken stirrer cover.
(4) Shaft binding—may be caused by worn bushings.

B. Air-driven systems:
(1) Air ducting, enclosures, or baffling displaced or deteriorated.
(2) Stirrer cover or grease shield warped.

C. Turntable models:
(1) Defective motor.
(2) Loose or broken belt. Or, disconnected wire.
(3) A turntable coupling (or the associated gears) that is burned or melted may fail to rotate with the weight of the turntable.

D. Magnetron oscillating off frequency, or producing a weak output.
(1) On units that provide two or more high-voltage taps (on the HV transformer), changing the high-voltage lead to a different tap can change the radiation pattern and possibly improve an otherwise poor cooking pattern.

E. If no malfunction is found, yet an unsatisfactory heating pattern exists, it may be that some models simply have an inherently poor heating pattern. Replacing the entire energy dispersion system may bring slight improvements.

F. Most microwave ovens that use stirrer or antenna systems require a certain amount of food rotation. The frequency and the degree depend primarily upon the type of food and the effectiveness of the energy dispersion system.

10. Oven is "dead":
A. Open line fuse.
B. Open thermal fuse.
C. Open power cord.
D. No power to the outlet due to a tripped external breaker or blown house fuse.
E. User has inadvertently turned *off* a hidden on-off switch.
F. Inoperative control panel with, coincidentally, the cavity bulb also burned out.
G. Interlock switch failure.
H. Burned, broken, oı disconnected harness wire, with the latter being more likely in newly-purchased models.

11. No heat:
(Symptoms may include a burning smell)
A. With primary voltage applied:
(Note: Does not apply to models with a high-voltage relay.)
(1) Defective magnetron tube or deficient filament connectors.
(a) A tube that is shorted internally may give off a strong ozonic odor along with a crackling and buzzing sound.
(b) A tube with an open filament, or loose filament connectors, is usually evidenced by a rather startling spark when the capacitor is discharged.
(2) Shorted or open diode. Usually accompanied by noticeable electrical burning odor and low pitched growl.

(3) Open capacitor.

(4) Shorted or open high-voltage transformer or separate filament transformer.

(a) Whereas most transformer troubles are readily obvious by smoke and smell, a *layer short* (short between the windings of two adjoining layers) in the transformer may not be otherwise detectable, except for the lack of proper filament voltage and abnormally hot operation. It may produce an odor of overheating and eventually will blow the fuse.

(b) Separate filament transformers may break down and arc on the secondary side.

(5) Improper connector crimp joint or poor terminal connections. This condition is usually associated with the filament wires and connectors.

B. In the absence of primary voltage:

(1) Interlock switch out of adjustment or defective.

(2) Open triac.

(3) Malfunctioning control unit or controller.

(4) Burned, broken, or disconnected wire. The latter is more prevalent in newly-purchased ovens.

(5) Open thermal fuse.

12. Programming problems:

A. Suspect the printed circuit board on any of the following (except *Sharp*-made units with a "*Stop*" switch which may be out of adjustment. Refer to *Section 9.6*): No response at all; no colons on the display with confirmed control voltage; missing segments; erratic-display brightness; jumbled characters; constant character; constant beep or buzz. See *Sections 13.3* and *13.4* for more details.

B. Suspect the touch (key) unit on any of the following: Display indicates number other than that which was pressed; only certain pads do not respond; certain pads require excessive pressure; while attempting to program, the display erratically resets to a particular number or character.

13. Shelf broken, cracked or has bubbled, blistered or melted spots:

A. Accumulated grease carbonizes, burns, and cracks or melts the shelf.

B. Areas in the RTV shelf sealer may deteriorate with age and allow grease to seep below the shelf. This usually results in one or more of the following: A bad odor or arcing and burning occurs in the cavity well and, as pressure builds, a broken shelf.

C. An inoperative or intermittent stirrer system will produce concentrations of energy on certain spots of the shelf, causing bubbling, melting, and breaking.

D. No-load or other abusive operation.

E. Flaws or impurities in the shelf itself.

14. Shocks people (electrically). Invariably, this is a result of the respective house circuit not being properly grounded or polarized, or both.

15. Shuts down (becomes inoperative) after period of operation, and will not come back on for a period of time. (Symptoms may also include the

outer case being too hot, and/or excessive moisture accumulating inside the cooking cavity.)

A. An overheating condition is cycling off the thermal protector due to:

(1) Blocked exhaust or intake opening, or both. Improper installation resulting in preheated air being drawn in through the intake vents.

(2) Internal air circulation problems, such as blocked or leaking air ducts and enclosures. This also may result in moisture accumulation.

(3) Malfunction in the blower assembly, such as a defective motor, or a slipping or binding blade (or wheel).

(4) Stalled stirrer blade or antenna creating reflected energy and causing the magnetron to overheat.

(5) Low-line voltage causing the magnetron to overheat—line voltage 10 percent below normal can be critical.

(6) A weak or moding condition causing the magnetron to become abnormally hot, despite a properly functioning cooling system.

16. Steam, vapor, or light escaping around the door:

A. In virtually all instances this is a normal occurrence. The door gasket is not a vapor seal. While the RF seal does quite effectively eliminate RF leakage, it is not air- or light-tight.

17. Timer hangs up:

A. While this may simply be a defective timer, before replacing it, check for possible knob and dial interference with either the faceplate surface or the openings in the faceplate. Ensure that the timer shaft is centered within the openings, and that the knob does not bottom-out against the faceplate.

18. Thumping, pulsating, or vibrating sound during cook cycles in lower power settings:

A. Triac breaking down—will probably eventually blow the fuse.

B. The timing of the gate signal output from the control panel could be amiss, resulting in high-voltage transformer rumblings due to high current surges and strong magnetic fields.

19. Trips the house breaker:

A. When a house breaker or fuse is consistently being tripped or blown by operating the microwave oven, as a rule the problem is an overloaded circuit. A weakened circuit breaker will also trip unnecessarily.

B. An oven malfunction can cause a house breaker or fuse to trip before the oven's own internal line fuse opens. However, it is only a matter of time before the oven line fuse opens, and resetting the breaker fails to restore oven operation. See item 5 of this outline.

Specific Problems: By Manufacturer

chapter 18

18.1 INTRODUCTION

Please note that the descriptions to follow are not intended to be all-inclusive or absolute, either in the nature of the failure, the corrective action, or the affected makes or models. The following section does provide a sampling of actual problems, established causes, and proven corrections. While most of these are common failures, they are also unique, and often unusual.

18.2 AMANA

Arcing in Stirrer or Antenna Compartment

A stalled stirrer blade can cause arcing and eventual burning. Check the airflow in air-driven systems, and the belt or motor in other systems.

Commercial (with prefixes RC, RV, ERC) models with motor-driven stirrer systems should have the stirrer blade suspended $^{9}/_{16}$-inch from the cavity ceiling. In domestic (with RR prefix) models with motor-driven stirrer systems, the blade should be $^{11}/_{32}$-inch from the ceiling. In each case the measurement is made from the top of the blade.

Arcing, Burning, and a Pungent Odor Coming From Within Cooking Cavity (RMC 20 and 30 Convection Models)

Similar to the *Thermador* problem described in *Section 18.12*, this is apparently the result of food particles and grease becoming trapped and accumulating in the gap between the rack guide and the cavity wall. Eventually, after being repeatedly subjected to microwave energy, the debris carbonizes and arcing occurs. Consequently, the adjacent rack guide material breaks down and arcs too (Fig. 18-1), resulting in a rather pungent burning odor. Correct the problem as follows:

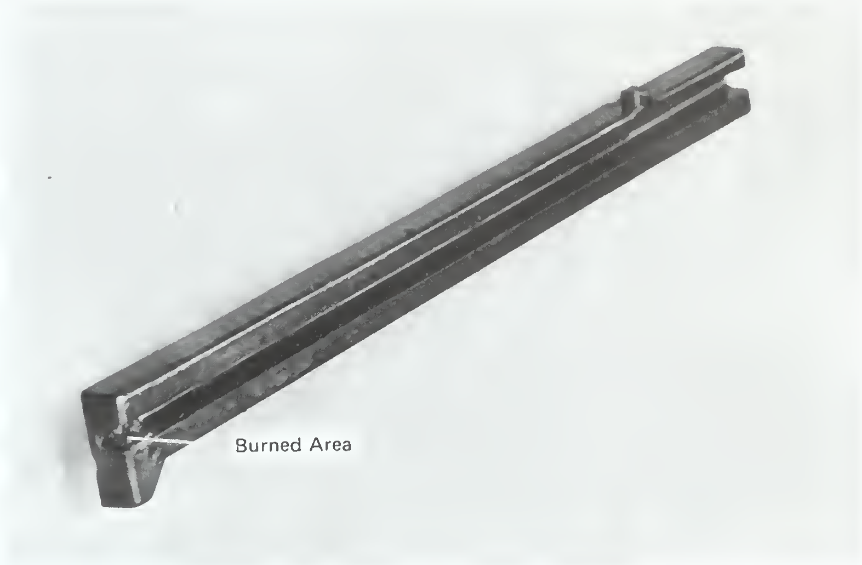


Figure 18-1 Rackguide burned from arcing.

Remove the affected rack guides and clean the corresponding area of carbon deposits, burned debris, and other food contamination. Clean behind the unaffected rack guides by spraying a mild cleaner-degreaser into the gap between the rack guide and cavity wall. Then, completely rinse out the cleaner with hot water. Ensure that the remaining rack guides are secured firmly against the cavity wall. Install the new, improved, replacement rack guides, available from the manufacturer as a standard replacement part, and secure them so as to minimize the gap between them and the cavity wall.

Finally, *always* check the floor-mounted antenna for proper rotation. If the antenna is turning in a jerky fashion, or not turning at all, replace the antenna-drive belt (*Amana* ref., O-ring) and, if necessary, replace the rubber pulleys (*Amana* ref., grommet).

Burning Smell Accompanied by a Crackling, Buzzing Sound (Domestic Models With the Swing-Down Type Door)

Check the filament transformer for arcing on the secondary side (Fig. 18-2).

Buzzing Sound That Occurs When "Started" in Microwave Cook Mode.

This is common in the earlier RMC COMBINATION CONVECTION/MICROWAVE models. The cause is the air-deflection solenoid not seating properly. The solution is either to adjust the original solenoid which is not often successful, or to replace the solenoid with the heftier solenoid that comes as a replacement.

Cavity Interior Burned, Grease Shield Melted, and Shelf Broken (Commercial Models of the RC10 and RC14 series)

These conditions are caused when the contacts of the *power* relay weld together. This places a constant voltage on the primary of the high-voltage transformer, interrupted only by opening the door. So, after the food is removed and the door is closed, the oven resumes full power—no-load—cooking, often unbeknownst to the operator.

When this occurs, in addition to replacing the *power* relay, the integrity of the

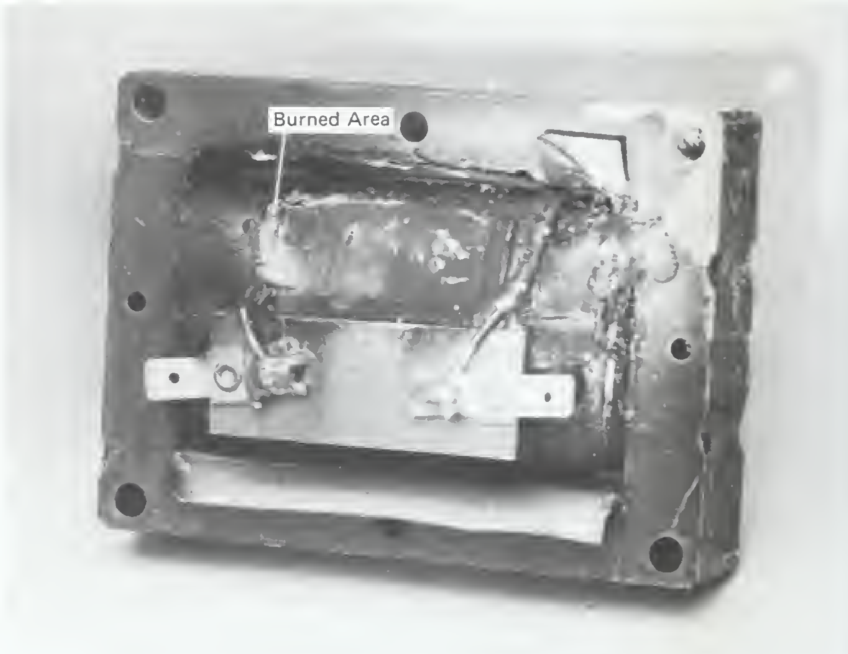


Figure 18-2 Filament transformer burned from an internal short.

surge relay contacts should also be checked. This can be done by removing the harness leads, energizing the relay using a line voltage jumper (cheater) cord, and measuring the resistive value of the contacts. Good contacts will offer less than 1 ohm of resistance.

The introduction of field-installed *surge monitor assemblies* and, then later on, *solid state surge relay kits* for these various models has virtually eliminated the problem. If the above problem is encountered, contact *Amana Refrigeration* concerning the appropriate kit for the particular model in question. (See Appendix V for the address.)

Control Module Dead, although Cavity Light Works (Domestic Models With Glass Touch Panels)

Check for an open magnetron *thermal* fuse. If that is the case, the blower motor should be strongly suspected—even if it appears to operate normally when tested. The operation of these motors can be very intermittent and remember, thermal fuses generally do not open without cause.

If the *cavity thermal fuse* is open, check for a stalled stirrer blade or antenna. This is usually due to an air-flow problem. Also, the prolonged and successive popping of microwave popcorn may open the cavity fuse.

Control Module Will Not Program Properly

Control modules with *glass* touch panels require a fully grounded circuit, and sometimes up to 24 hours of warm-up time before they will respond properly.

Cycle Conversion

On export models equipped to allow conversion from 60 to 50 cycles (HZ), or the reverse, the instructions for the conversion are provided, either on the inside wall

of the side panel or on some other interior surface. As a rule, these models are identified by the suffix *ET* to the model number.

Operating these ovens on 60 HZ while set for 50 HZ will eventually cause the following: 1) an open line or thermal fuse, 2) a premature failure of components due to overheating, 3) inaccurate readout of the programmed cooking times and time of day, 4) dial timers appear to run slowly.

Door Handle or Latch That is Binding—Commercial Models (RV and RC Series)

This binding is caused by either broken springs within the handle assembly or the latch spring (above the latch-interlock switch) binding on the plastic latch strike (through which the door hook protrudes when the door is closed). Appropriate adjustments should be made and, if necessary, replace the handle assembly. Inspect the latch strike for wear or breakage. If the latch strike is replaced, be sure *not* to install it *upside down* or *backwards*—it is an easy mistake to make.

Fuse Blown—No Apparent Reason

In *Amana* models only, unless otherwise directed, replace failed 15 amp fuses with a 20 amp fuse.

Heats Unevenly (Domestic Models)

An air-flow blockage, or more often leakage, is inhibiting the rotation of the stirrer or antenna blade. This is caused by one or more of the following: sagging grease shield, deteriorated air-gasket material, binding or slipping blower wheel, or a defective blower motor.

Routine service procedure on all Amana models should include verification of the rotation of the antenna or stirrer blade.

Interlock Protect Thermal Fuse Opens For No Apparent Reason (Domestic Models With the Swing-Down Type Door)

The left interlock switch becomes out of adjustment as a flat spot wears in the counterbalance arm roller. For some reason, and thankfully so, this condition seems to be predominantly left-side oriented. To correct this problem, a roller kit is available from *Amana*, part number R1571-45. Anytime service is performed on an *Amana* with counterbalance arms, ensure that the rollers freely rotate; lubricate if necessary.

Oven Becomes Inoperative After Several Minutes of Operation. Then, After a Few Minutes, Operation Can be Resumed (RMC Models)

Suspect the *cavity thermal cut-out*, which is located on the exterior of the upper right-hand rear wall of the oven cavity. Inspect the terminals of the thermal cut-out for a burned, charred appearance, similar to the one pictured in Figure 18-3. This condition is caused by either a faulty internal terminal connection, or loose connector-to-terminal connection. Replace the thermal cut-out and repair or replace any burned connectors or wires.

Thumping While in the "Cookmatic" Mode (All Models With Electronic Controllers)

This is caused by the control module's internal triac operating on an erroneous time base. Replace the control module.

Figure 18-3 Charred appearance due to a faulty internal connector.

18.3 GENERAL ELECTRIC/HOTPOINT/JCPENNY

Door Seems Loose When Closed (Models Manufactured in the Late 1970s)

This is the nature of these doors. A certain amount of tolerance increases the quality of the door closure and minimizes wear. If necessary, however, *latch shims* can be removed from the latch bar to tighten the fit. *Always check the RF Leakage after repairs.*

Power Selector Switch Failure (Usually 3-Power Level), Either Push-Button or Rotary-Type; Usually Evidenced by Burned Wires and Terminals (Models Manufactured in the Late 1970s)

This condition can be caused by an open *power resistor*, which is the large 3-terminal (center-tapped) resistor located next to the rear of the component compartment. Normally the resistor should read about 1950 ohms between the two end terminals. If the resistor is *open*, or if an abnormal reading is obtained, *replace* the resistor. Failure to do so will cause premature failure of the new replacement selector switch.

Shelf Discolored (Auburn), For No Apparent Reason (Models Manufactured in the Late 1970s)

This is a flaw in the shelf, in which a chemical action, caused by microwave energy, produces a discolored or transparent area. The old shelf should be removed and a replacement installed.

18.4 HOBART

(Models of the M310 and M312 series)

Five-Second Warm-Up Inoperative—Will Not Go Into Cook.

Defective 5-second relay board.

Uneven Heat

Check for one or both stirrers to be stalled, or at least operating intermittently. An improved replacement stirrer system, available from the manufacturer, has subsequently minimized this problem. NOTE: The stirrer blades are removed by unscrewing them *counter-clockwise.*

18.5 LITTON

Arcing In the High-Voltage Section

(1) Improper magnetron phasing, or other miswiring. Inadequate high-voltage wire spacing.
(2) *System 80* commercial models: high-voltage arcing over the insulator cup on the high-voltage capacitor, the results of which are shown in Figure 18-4. The capacitor should be replaced with an improved (taller-insulator) capacitor which comes as a standard replacement part from *Litton* (see the respective parts manual for the appropriate part number).

Arcing In the Stirrer Compartment

As shown in the picture in Figure 18-5, arcing may occur in the area where the *stirrer support bar* is mounted to the flange. Evidently, accumulated grease or trapped food particles carbonize and trigger the arcing. To correct the problem, clean the area of all traces of carbon, grease, or other contamination. If necessary,

Figure 18-4 The results of insulator arc-over.

Figure 18-5 Arcing stirrer support bar.

touch up the affected area with cavity paint of an appropriate color. Replace the stirrer support bar with the improved replacement part, which is available from the manufacturer.

Blower Assembly Is Noisy

Either, 1) the blade (or wheel) is loose on the shaft, or, 2) in *Generation II* models, the fan blade is rubbing the blower housing. In the first case, replace, or reposition and glue the blade (or wheel) to the shaft. In the second case, either adjust the mounting bracket so that the motor is centered in the housing, or remove the blade and evenly trim its perimeter by no more than 0.010-inch. Since, in this second case, the noise may disappear with the outer cover removed, the repair should be tested with the cover installed.

Blower Motor Runs All the Time

Models 1437.A, 1439.A, 2237.A, and 2239.A: The oven relay (K1) mounted on the printed circuit board sticks in a closed position. Replace the control board.

Control Panel Operates Erratically

These symptoms may include an abnormally rapid countdown, intermittent stopping of the countdown, or erasure of the display resulting in oven shutdown. The symptoms may also *disappear* when the outer case is removed. This may be caused by one or more of the following related conditions: 1) An RF leak somewhere within the component compartment causing interference with the operating signals of the control circuit microprocessor. In this case, the source of the leakage should be found and corrected. 2) Electromagnetic interference generated by the transformer and magnetron is in phase with the operating signals of the microprocessor. This problem can be corrected by reversing the leads to the primary of the low-voltage (control) transformer, which places the control signals out of phase with the interference so that the former is unaffected by the latter. 3) Arcing in the high-voltage section due to miswiring or improper spacing. 4) This symptom in *com-*

mercial units may also be caused by excessive RF leakage from the edge of the door adjacent to the electronic timer.

Display Fades Out or Is Erratic. Also, Intermittent or No Power to the Control Panel—Model 1580

This symptom is usually caused by the interface-board connector becoming oxidized and thus deteriorating the connections. This condition can be repaired by removing each of the harness wires from the interface-board connector, one at a time. As each wire is removed, carefully solder it to the appropriate terminal on the interface board. Replacement interface boards come as such.

With a symptom of *no power* to the control panel, suspect an open low-voltage transformer, which is located on the interface board.

Door Handle Is Hard to Push Down Series 400 models.

These units have L-shaped latch bars, to which the interlock switches are mounted. Ease the stress by prying the tab at the bottom right side of the "L" back away from the frame slightly (see Fig. 18-6). Also, lubricate the friction points so the latch bar rides up and down freely.

Door Latch-Hook Broken—Domestic Models

The latch-hook assembly is available as a replacement part—consult the parts manual. After replacing latch-hook assembly, the door must be adjusted to elimi-

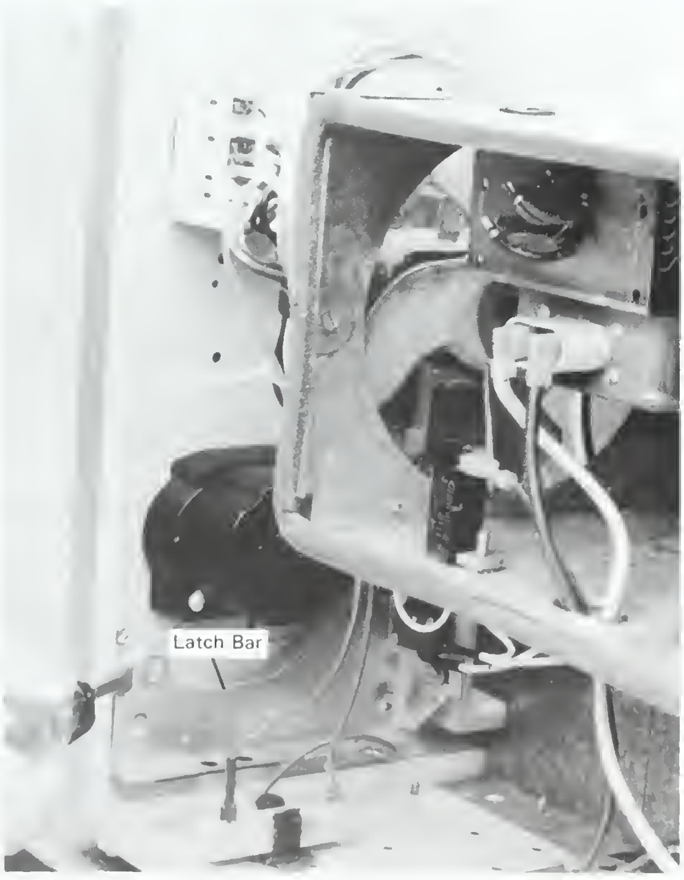


Figure 18-6 Improving latch-bar operation.

nate the cause of the original break. (This usually involves adjusting the door *upward.*)

Flickering Neon "Cook" Light

While some flickering of this type of bulb is normal, a noticeable increased intensity in the flickering may well indicate an unusually high magnitude of RF emissions within the component compartment. Since this stray energy is confined by the outer cover, it deflects around, causing various symptoms, eventually dissipating or escaping through an air vent. When the cover is removed, the abnormal flickering of the "cook" light will usually subside. The source of the leakage must be isolated and eliminated, or at least minimized. In most cases the magnetron RF gasket will likely be burned, or otherwise deficient, and replacing it will correct the problem. However, the magnetron can also have a structural defect that can allow internal leakage. In this case, depending on the amount and effects of the stray RF energy, the magnetron tube should be replaced.

Fuse Opens During Operation—No Apparent Reason

If there are indications that the fuse element melted rather than blew, check for weak fuse clip spring tension, loose rivets inside the fuse holder, a burned spot on either of the fuse end caps, or loose terminal connections. These conditions cause resistive heating which reduces the fuse's current carrying capability until, usually during peak operating periods, the fuse opens.

Handle Loose—Commercial Models

Litton's latest efforts at a commercial door handle that will fasten tightly and stay that way are: For *System 70* ovens, a single set screw and a nylon locking pad (although any appropriate shim will usually suffice). For *System 80* ovens, the handle is secured by *two* set screws. In the latter case, the *bottom* screw should be tightened *first*.

Heats Intermittently

Loose or improperly crimped filament connectors on the high-voltage transformer filament leads begin to erode, and the connections deteriorate to the point that the magnetron intermittently ceases conduction. Check the terminals and connectors for signs of looseness or overheating. Repair or replace as necessary. Inspect the magnetron terminals. If they are burned, pitted, or otherwise damaged, the magnetron should be replaced also.

Intermittent Operation—Commercial Models

See the next heading

Latch Strike Broken—Commercial Models

(Usually causes intermittent operation, and seems to be predominantly the lower latch strike.)

Before concluding this to be a simple plastic break or switch adjustment, check the *latch bar mounting pivot pin*. Check for excessive front-to-back movement of the door hook. To examine the latch-bar assembly, the outer door must be popped off (see *Section 15.10.1*). If the mounting nut is missing, look in the bottom of the outer door panel. The addition of a star washer between the mounting bracket and nut will prevent the nut from loosening again.

Magnetron Oscillates a Moment, Then Gradually Loses Oscillation

While this may be the symptom of a *moding* magnetron, it may also be caused by loose filament connectors and, even more unusually, a transformer winding that opens only after it heats up.

No Heat, Will Not Start, or Is Completely "Dead". Occasionally This Complaint Also Includes a Faint Electrical Burning Odor

Model 7000 over-the range units: Inspect the interlock switch wiring for burned connections. Replace the connectors as necessary. If the wire is burned brittle, cut away the bad portion and splice in a new length of wire with a wire nut or by soldering. Models 7000.000 should always be checked for this condition.

Programming Problems—Model 7000

Whereas this is usually corrected by replacing the touch panel, occasionally the ribbon *connector* on the printed circuit board has one or more weakened or deformed internal spring clips. These can be identified and, using an appropriate tool, delicately reformed to restore contact with the ribbon terminals.

Push-Button (Solid State) Timers Keep Burning Out—Commercial Units

In certain revisions of the *70/50* series of commercial ovens, the voltage supply to the solid state push-button timer is center-tapped from the primary winding of the 220-volt-AC auto-filament transformer. The primary winding, or center tap thereof, can open in such a way so as to blast the 110-volt solid state control circuitry with nearly 220 volts AC. Burned resistors and diodes on the printed circuit board are indications that this type of filament transformer failure is lurking.

Thumps As It Goes Into Cook

As the magnetron pulls into conduction, a slight pulse is normal, but a loud thump is likely caused by a defective triac.

Screws Will Not Loosen

Two methods of breaking loose obstinate phillips-head mounting screws are: 1) Attempt to tighten the screw by an eighth of a turn or so. This may break it loose and, even if the slots strip in the forward direction, the screw can still be backed out. 2) Place a piece of wood over the screw and tap the wood with a hammer.

Waveguide Burned Around the Antenna Pin

Primarily in the earlier 500 *Meal-in-One* series, look for a loose antenna pin. Usually the waveguide is unharmed and only the hex-head bolt that serves as the antenna pin need be replaced. Be sure to file the surface so the bolt head makes good contact with the waveguide.

Will Not Start—Model 1580

If the control panel programs normally, and the proper operation of the start pad is verified by setting the clock, check for a faulty connection in the control panel connector.

18.5.1 Litton Jet-Wave™

(First generation models)

Clean Cycle Repeats

This may be a defective cavity thermal protector that is hesitating between its two positions. Also, an interruption of the supply voltage during the clean cycle can cause the unit to repeat the cycle.

Counts Down, Then Stops and Holds Whatever Is On the Display

Open and close the door several times to see if the unit restarts. If the oven can be restarted, this indicates that the low-level door logic signal is being inhibited to an extent by the contacts of the two door logic switches. Even though these switches may check normal, they should be replaced with the improved gold-contact replacement switches.

Insufficient Output

Before making a service call, make sure that the time element in the cook's recipes is adequate for the amount and type of food being cooked.

18.6 MAGIC CHEF

(Models manufactured in the late 1970s and early 1980s)

Control Panel Sometimes Will Not Respond to Certain Touch Pads

Normally the primary suspect in this case would be the touch panel, as opposed to the control panel. However, experience has shown that in *Magic Chef* models it seems to be just the reverse. If the symptoms are intermittent, or a matrix diagram to test the touch pads is not available, try replacing the control panel as a first choice.

Fuse Blown—No Immediate Indication as to the Cause

After replacing the fuse and initiating a cook cycle, the oven initially groans and noticeably pulls down the voltage, but then seems to function and heat normally. In this case replace the triac.

Door Hard to Open or close

In older models (*MC* series and the *MW 300* series) the latch, which extends inside the door assembly, will wear to the point that latching and unlatching the door become quite difficult. Often, the latch breaks and the door cannot be opened at all. Replacing the latch, available from the manufacturer, requires disassembly of the door. These older door-latch mechanisms are adjusted by the addition or removal of special latch-strike spacers.

In the *MW 200* series the door latches tend to break off completely, with the only repair option being the replacement of the entire door. When these doors seem unusually difficult to open, often the remedy is to simply lubricate the latch roller. Sometimes the door hook wears a groove in the latch roller that produces significant binding when unlatching or latching. In this case the roller assembly should be replaced.

Uneven Heating

Look for a broken or displaced stirrer drive belt.

18.7 PANASONIC

Buzzing (Arcing) Sound, and No Heat

Typically this symptom produced by the variable *power switch* breaking down and arcing internally. Replace the variable power switch.

"FFFF" Comes Up on the Display When the "Start" Pad Is Pressed

(Models affected include NE9910, NE9910C, NE9910A, NE9930, NE9930C.)

Locate the *oven temperature sensor*. The sensor is mounted toward the rear of the cavity ceiling exterior, along the center of that edge. It is hidden beneath an adjacent enclosure, but its leads can be recognized as they extend vertically out of the sensor compartment. Remove the sensor and inspect it for corrosion and breaks in the lead wires.

Shelf Breaks For No Apparent Reason (Commercial Units Only)

Presently, the precise cause of this shelf-breaking problem is undetermined, and may affect only a limited number of units. The apparent defect seems to be in the shelf itself, although some units have broken more than one shelf. To date, the correction is to replace the shelf.

18.8 SAMSUNG

Oven "Dead", Fuse Open—No Apparent Reason

Look for evidence of the line fuse element having melted, rather than blown. The former being the case, replace the fuse and the fuse holder.

18.9 SANYO/SEARS (KENMORE)

Heats Normally At First, Then (After Maybe Several Minutes) Gives Way to a Low Hum and Stops Heating

The magnetron is breaking down and must be replaced.

Intermittent Heating

Check the primary terminals of the power (high-voltage) transformer for poor or improperly crimped leads. If this is suspected or proves to be the case, scrape back the coating from the enameled wire and solder each connection.

Intermittent Control Panel Operation

(May also be described as erratically stopping during a cook cycle or intermittently not starting when the "start" pad is pressed.)

This problem is very likely caused by the improper adjustment of the *door sensing switch*. The switch plunger must be depressed to a point that is 1/32-inch (0.8 mm) or less from the switch body, otherwise its operation will be undependable.

Oven "Dead", Fuse Blown—No Apparent Reason

This failure may occur when a leakage path forms between pins of the *photo-coupler* on the printed circuit board, activating the circuit in an abnormal manner. The corrective action involves the application of a non-conductive sealer between the pins of the photo-coupler—see *Section 14.10, item 4* for details.

18.10 SHARP/MONTGOMERY WARD

Control Panel Will Not Program

Stop switch out of adjustment—see *Section 9.6.*

Blower Fan Comes On by Itself, or Runs All the Time

Convection models: Visually examine the thermistor for a broken or shorted lead caused by corrosion.

Convection Operates for a Few Minutes Then Shuts Off

Again, check the thermistor for corrosion. Also, check the damper motor and damper switch for proper operation.

Turntable Fails to Rotate

Do not hastily assume that the turntable motor is defective. On models R8580, R8475, R8580A, R8475A, and R8575A check the *motor switch* first. The motor switch is mounted just above the lower interlock switch, and may simply be out of adjustment. Using appropriate precautions, adjust or replace the switch as necessary.

Convection ovens, models R8475 and R8580, may have an additional problem. In this case, the *upper interlock switch* may be adjusted to high, which does not allow proper switch actuation by the door latch head. Adjust the upper latch assembly downwards so the switch actuator is sufficiently depressed when the door is closed. NOTE: Ensure that the in-out movement of the door is limited to less than 0.5 mm (about 3/32-inch) in the latched position. In other words, make sure that the interlock switches interrupt the circuit *before* the door can be opened more than 0.5 mm.

Also, check the lower switch assembly to ensure that its proper alignment was not disturbed by the previous adjustment.

Check for microwave leakage around the door with an approved microwave survey meter as outlined in *Section 15.7.*

18.11 TAPPAN

"Dead", Fuse Blown—No Apparent Reason (Older Models With Screw-In Type Fuses)

Vibration causes the fuse to gradually loosen, diminishing and heating up the contact point, until the fuse melts internally. If the fuse looks normal from the top, turn it over and look at the bottom contact. If the fuse was too loose, the contact will be burned and pitted. Simply clean up the receptacle contact, and install and securely tighten down another fuse.

Dead; Oven Overheated and Thermal Fuse Opened

Some 1.3 cubic foot ovens, manufactured in the last quarter of 1986, overheat

and open the thermal fuse for no apparent reason (because the blower seems to operate normally). However, the hubs of some of the original blower blades will crack and loosen on the shaft. As a result, the blade never achieves sufficient RPMs (rotations per minute), the magnetron overheats, and the thermal fuse opens. Since replacement blades do not have this problem, simply install a new blade and replace the opened thermal fuse.

Stirrer Blade Scraping

In belt-driven models, the bushings tend to wear and the belt tension tilts the stirrer shaft, causing the blade to scrape the cavity ceiling or the stirrer cover. The solution is to replace the bushings.

18.12 THERMADOR

Arcing and Burning of the Rack Guides (Convection Models)

Whether this problem is caused by the customer's improper insertion of the metal rack or, more likely, by food particles and grease that become trapped between the rack guides and the cavity wall and eventually carbonize, arc, and burn, the condition is corrected as follows: Remove the burned rack guides and clean out residual carbon deposits and burned areas on the cavity wall. Before installing the new, improved rack guides, available as standard replacement parts, apply a *thin* coat of a special gasket sealer, which is available from *Thermador* distributors, between each new rack guide and the cavity wall. Install and secure the new rack guides, and wipe away any excess gasket compound.

Stirrer Intermittently Not Starting

In the *MC17* models the stirrer shaft extends through two holes before entering the cavity. In some units these holes are misaligned, which causes an intermittent bind in the stirrer shaft. If, in the unlikely event, this is encountered, file the holes so the shaft hangs through both of them without touching either rim.

18.13 TOSHIBA

Oven Dead, Inaccurate Control Panel Timing, or Weak Heat (With an Unusual Hum)

These are all symptoms of an oven that is set for the wrong operating frequency. For example, if an oven set to operate on 50 Hz is brought into the United States and operated, without having been appropriately converted to 60 Hz operation, the consequences will be one or more of the symptoms just stated.

18.14 WHIRLPOOL/KELVINATOR/GIBSON

Arcing, Buzzing Sound and No Heat

In models using the old-style *Litton* magnetron tubes (glass or ceramic dome), suspect a defective magnetron. Replace the magnetron with the appropriate magnetron kit. This replacement kit, available from the manufacturer, includes a superior magnetron tube and, depending on the model, a different-rated high-voltage capacitor. Follow the installation instructions carefully.

Cook Button Will Not Work—Will Not Stay in Cook After the Button is Released (Models Manufactured in the Late 1970s)

Check the 3 ohm surge resistor connected to the cook relay. If the resistor is open, replace the cook relay. Rarely, the temperature (probe) control unit will fail to supply appropriate voltage to hold the relay energized. Although this failure occurs infrequently, when it does the problem is in the temperature unit, and not the relay.

Diode (High-Voltage) Fails Repeatedly or Prematurely

Check the high-voltage capacitor to ensure that it is properly grounded. In models REM 7400, check for a failed *infinite power control unit*. Repair or replace parts as necessary.

Heats Inadequately or Intermittently

Refer to the first symptom under this heading.

Indicator Light, Usually the "HOLD" Light, Remains On

Refer to the next paragraph.

Programming Functions Are Erratic, Will Not Accept Programming (Models: RHM988, RM278, and 988.)

These conditions can result from abnormal continuity existing between the metallic strips on the ribbon connector of the touch panel. If this condition is judged to be the source of the problem, the corrective action is to replace the touch module.

18.15 IN CONCLUSION

The preceding sampling of symptoms, problems, and cures include those which are dated, and thus, some will become out-dated. Others, due to their peculiar or unusual nature, may never be encountered precisely as described. And still others may manifest symptoms that do not match the respective models or associated failures. However, these examples do offer a realistic idea of the type of failures that can and *do* occur. Furthermore, in the likely event that some of these failures are encountered, the advantage of foreknowledge will provide a definite and beneficial troubleshooting edge.

Hence, coupling this awareness with the knowledge gleaned from *Chapters Twelve* through *Sixteen*, which describe the reasons and ways in which failures occur and then, adding to that the understanding of component construction and operating characteristics, as gained from *Chapters Seven* through *Eleven*, may the servicer be well-equipped and worthily prepared for the safe, effective—yes, successful—service and repair of microwave ovens.

Touch Panel Test and Reference Matrix Diagrams

Appendix I

Precautions to be observed while testing the mylar touch panel (also variously referred to as the key unit, soft-touch panel, or membrane touch panel).

Do not over-flex the ribbon cable, either forward or backward—this may damage the silver circuits.

Do not use pointed test leads and be careful not to scratch, scrape, or pierce the ribbon (flex) cable.

Do not touch the electronic control panel—electrostatic discharge will damage static-sensitive circuitry (see *Section 8.6)*.

1. Unplug the oven, remove the cover and DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).

2. Remove the control panel and touch panel if sufficient access cannot be achieved while installed in the oven. Set the control panel aside while testing the touch panel.

3. Gently remove the ribbon cable from the circuit board by applying even pressure to both sides of the ribbon, then pull the ribbon outward from the connector. If the circuit board terminal socket has a fastener or clip such as is shown in Figure I–A, remove the flex-cable as follows: Using the forefinger, press in the

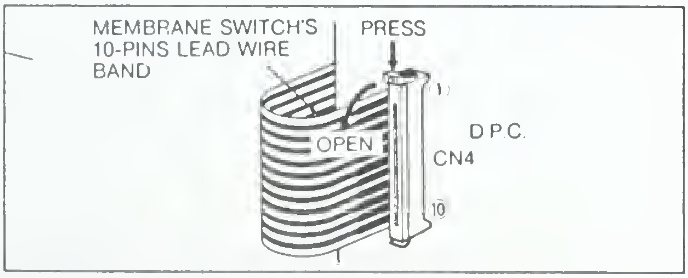


Figure I–A RELEASE FASTENING LEVER (Used by the permission and courtesy of Matsushita Electric Corporation of America—source material copyrighted 1983.)

lever end slightly to release the fastening clip, then gently raise the lever end of the fastener. Remove the flex cable from the connector.

4. The test is performed by measuring across the two appropriate flex tail test points, as indicated in the appropriate matrix chart. The matrix diagram shows which two points will make contact when the corresponding pad is pressed. Without any pads being pressed, the resistance between any two points should never be less than 1 million (MEG) ohms. When a pad is pressed, the resistance across the two respective connecting points for that pad should be typically less than 100 ohms, although some may indicate continuity reading as high as 50,000 ohms. An ohmmeter setting of at least R X 1000 is a suitable range for testing most, if not all, touch panels.

5. If any silver is missing from the edge of the cable, those without fastener holes can be repaired by carefully trimming an even 1/16-inch off the end of the ribbon cable. This provides a renewed electrical connection to the circuit board connector.

6. When reinserting the ribbon cable into the board connector, apply even pressure to both sides of the flex tail for full and even insertion. If a locking lever is used, hold the fastener with the thumb and forefinger of one hand, then slowly and evenly insert the flex cable into the connector with the other hand. Be sure the holes in the ribbon cable are properly engaged with the hooks on the plastic fastener before latching the lever.

To illustrate the correct way to read a matrix diagram, refer to the *Tappan* matrix shown in Figure I-B. For example, to check the "6" pad: touch one meter probe to pin #4, then touch the other probe to pin #7. Pressing the "6" pad should close contacts "A" to "B", thus producing a reading of continuity on the meter.

In each case, find the appropriate matrix for the particular microwave oven brand and model number you desire to test, then perform the test. Although matrixes of the various brands, and even models within a brand, are diagrammed in different ways, the same principles of testing apply. Find the two ribbon-connector pins that are common to the pad to be tested, then check for continuity across those pins while pressing the pad.

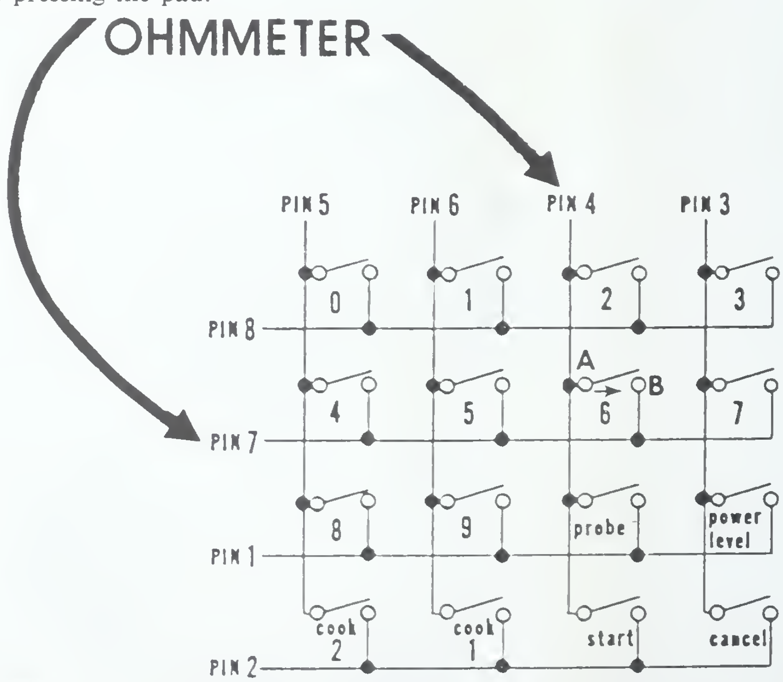


Figure I-B HOW TO CHECK A MATRIX (Reprinted with the permission of White Consolidated Industries, Inc.)

TO TEST THE RED (L.E.D.) LAMP PORTION OF THE ASSEMBLY:

1. DISCHARGE THE HIGH-VOLTAGE CAPACITOR(S).
2. Disconnect the flexible circuit strips.
3. Zero the ohmmeter on the R X 10K ohm scale.
4. Attach the negative meter lead to the common (C) terminal.
5. Check each of the other terminals with the positive lead of the ohmmeter. In each case the meter should indicate INFINITY.
   NOTE: Keep fingers away from the meter leads and the terminals of the flexible strip, as body resistance will produce an erroneous reading.
6. Disconnect the ohmmeter leads from the flexible strip.
7. Connect the *positive* ohmmeter lead to the common (C) terminal.
8. Check each of the other terminals with the negative lead of the ohmmeter. In each case the meter should read approximately 70,000 ohms—except the circuit strip between #8 and #12.
9. If the readings are substantially different from those indicated above, then replace the switch-indicator lamp assembly.
10. Test the yellow "READY" (L.E.D.) lamp in the same manner as above.
    A. With the negative meter lead on the "R" terminal and the positive meter lead on the "C" terminal, the meter should read approximately 70,000 ohms.
    B. Reversing the meter leads should produce a meter reading of INFINITY.

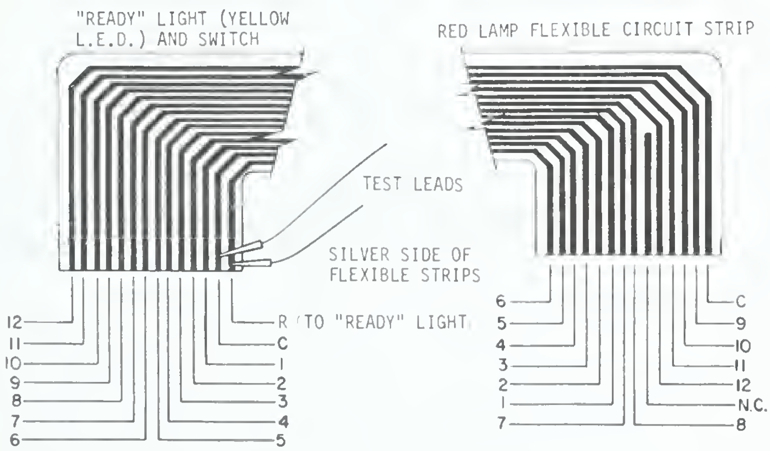


Figure R-1 (Refer also to Fig. R-2) Model RC10S—Original Timer-Switch Assembly—Amana Membrane Switch/Indicator Lamp Assembly Test.

(Above information supplied courtesy of Amana Refrigeration, Inc.)

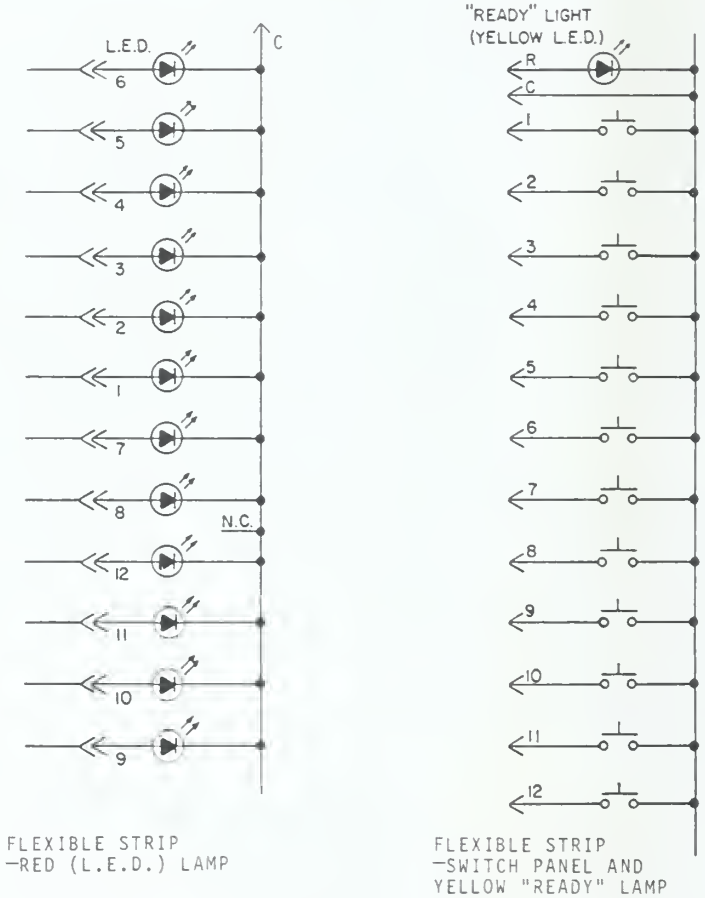
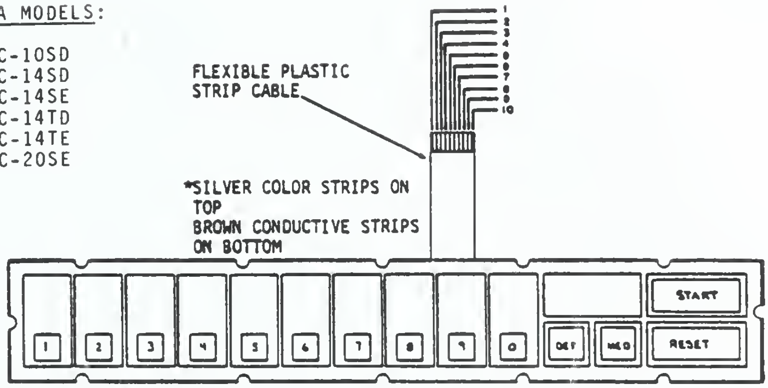


Figure R-2 Model RC10S—Original Timer-Switch Assembly—Amana Membrane Switch/Indicator Lamp Assembly Test. (Contd.)

(Above information supplied courtesy of Amana Refrigeration, Inc.)

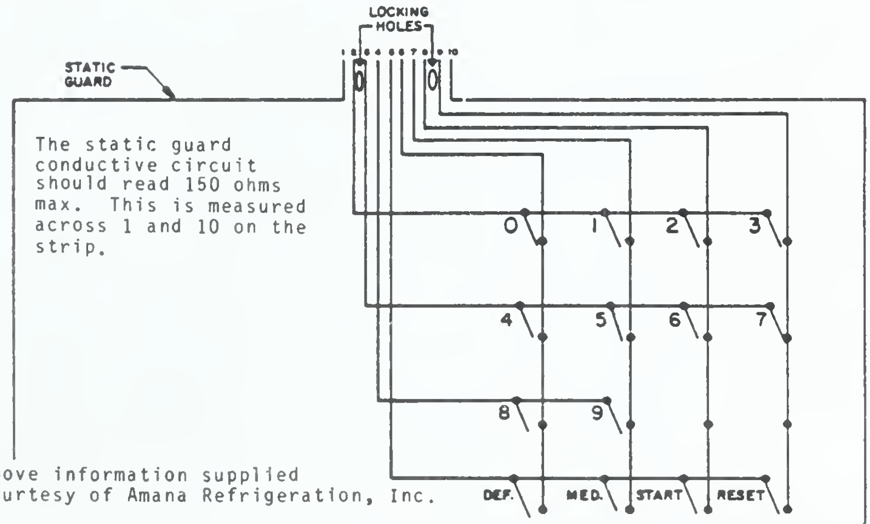
AMANA MODELS:

RC-10SD
RC-14SD
RC-14SE
RC-14TD
RC-14TE
RC-20SE



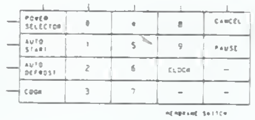
*CAUTION: DO NOT BEND THIS STRIP CABLE INTO A SHARP RADIUS OR SEPARATION OF THE CONDUCTIVE MATERIAL CAN OCCUR CAUSING AN OPEN CIRCUIT(S).

PIN #	STATIC 1 GUARD	2	3	4	5
6		0	4	8	DEF.
7		1	5	9	MED.
8		2	6	N.C.	START
9		3	7	N.C.	RESET
STATIC 10 GUARD					

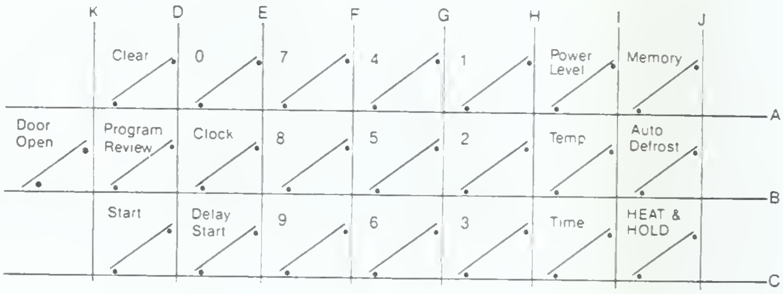


Above information supplied courtesy of Amana Refrigeration, Inc.

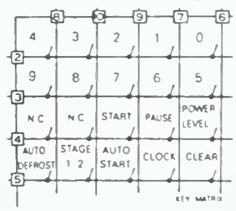
MODEL: AT736A



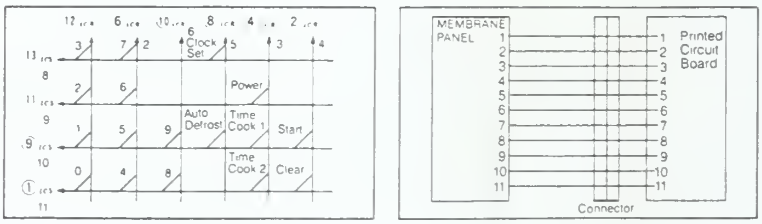
MODEL: AT1100



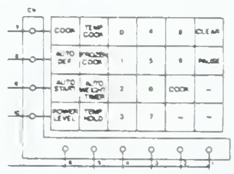
MODEL: AT1350



MODEL: AT1551

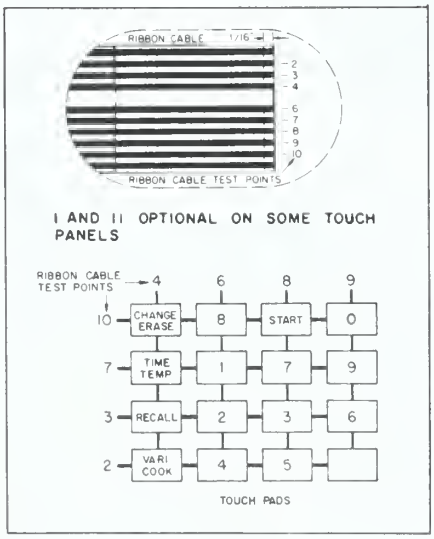


MODEL: AT1555

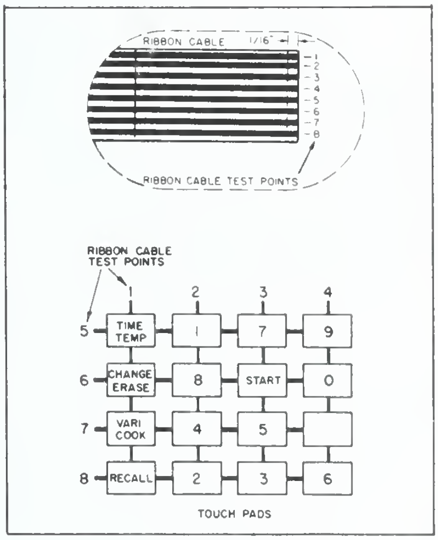


Courtesy Emerson Radio Corp.

MODELS: K-420.500, K-460, K-540, L-760, 1035, 1041, 1050, 1051, D-1150, K-1250, 880.003, 880.004, 1550, 1551



MODEL: 465



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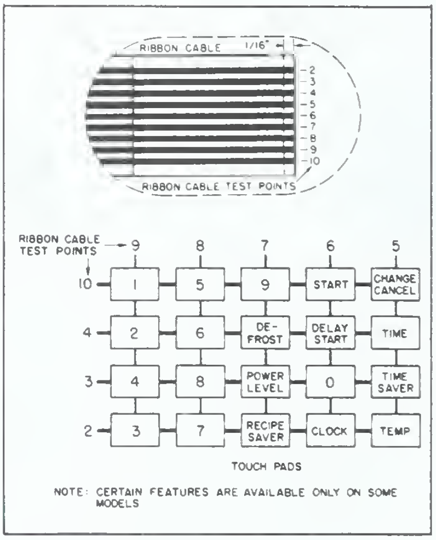

MODELS:

K-560	1442	1971
874	1450	2036
945	1453	2039
1052	1460	2052
1054	1462	2054
1056	K-1560.000	2070
1072	1635	2072
1074	1636	2074
1145	1639	3072
1146	1739	3074
1150	1750	3090
1320	1752	7154
1325	1936	8072
1335	1951	8074
1440		

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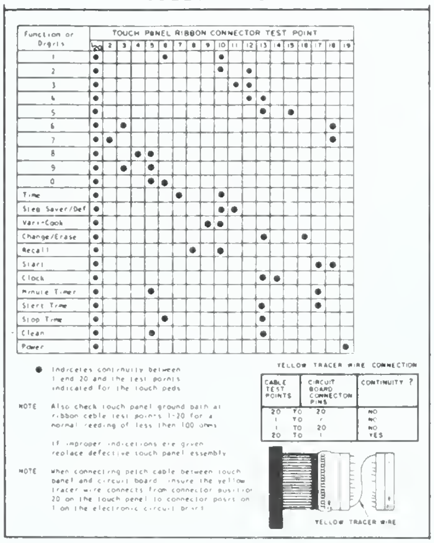
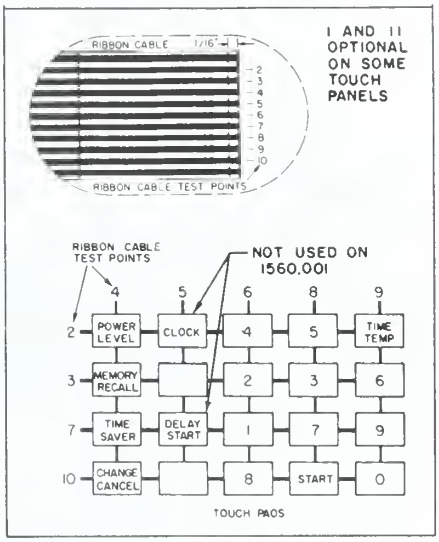
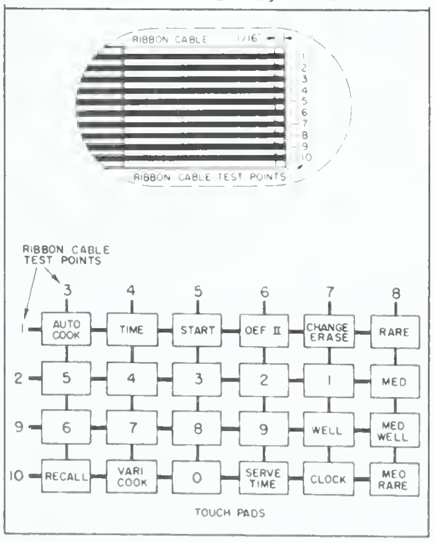
MODEL: 776



MODELS: 1270, 1560.001,
1570, 7000, 7160



MODELS: 1280, 1580



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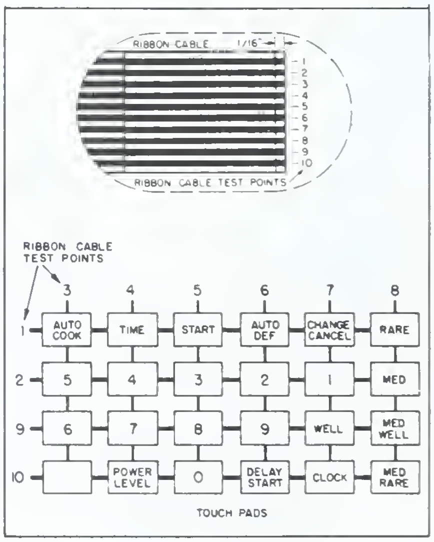
MODELS: 1585 1590 1990 1995 2085 2089 2090 7190 8090 UC0300



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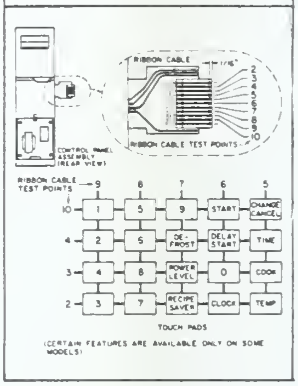
Models: 1639, 1936, 1951, 1971, 2036, 2039, 2052, 2054, 2070, 2071, 2072, 2074



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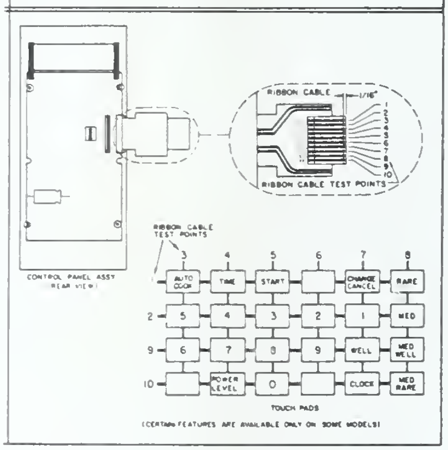
Model 1780



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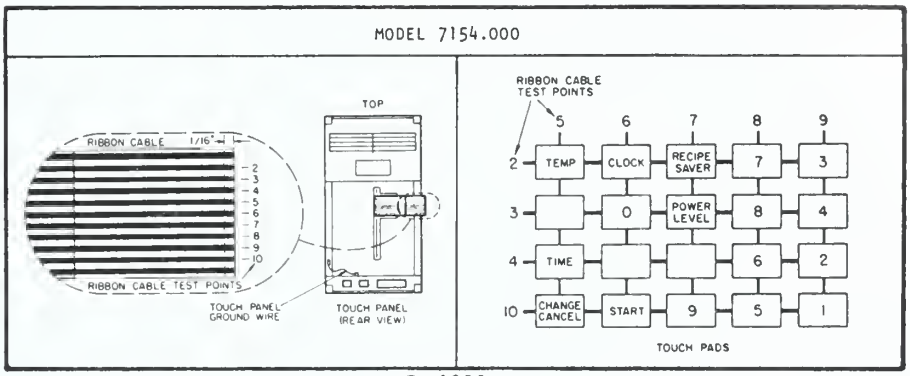

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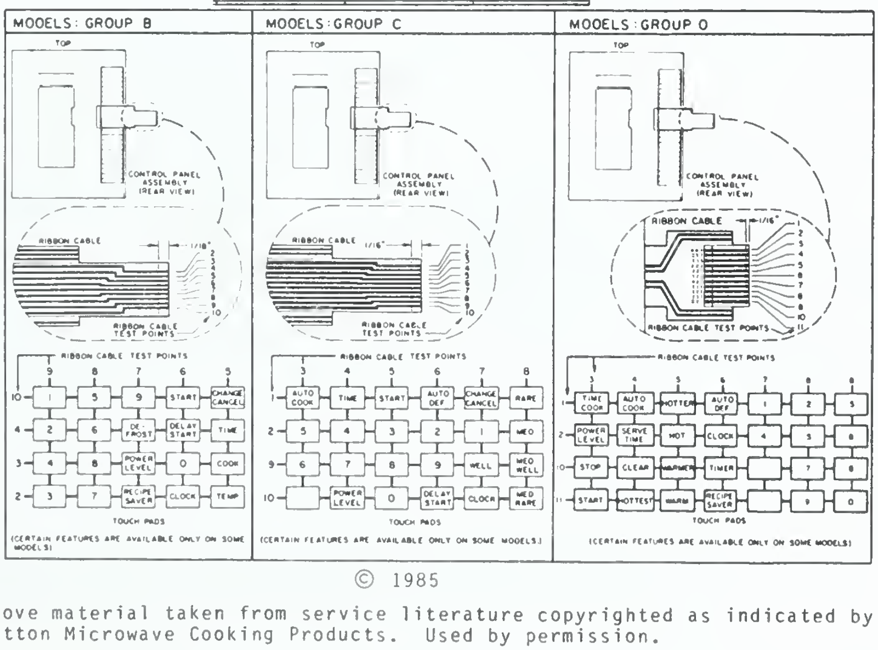
GROUP B	GROUP C	GROUP D
8072.000 8072.004 8074.000 8074.004	8090.000 8090.004	8094.004



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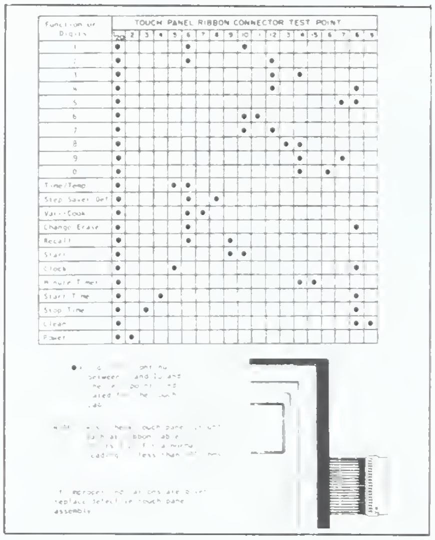
MODELS: 1880, 1890



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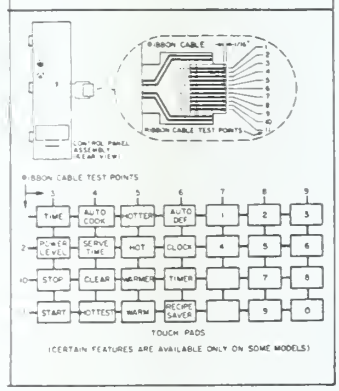
Models: 2091.004, 2092.004,
2094.004, UCO-300.004



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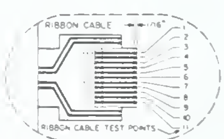
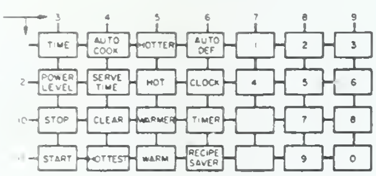
MODEL: 3094.A00



NOTE
RESISTANCE SHOULD MEASURE LESS THAN 100 OHMS BETWEEN RIBBON CABLE TEST POINTS WITH THE CORRESPONDING TOUCH PANEL PAD DEPRESSED



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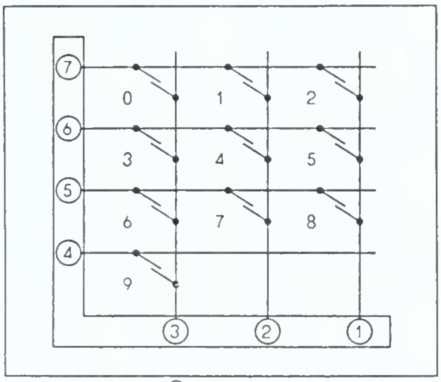
MODELS: NE-1050, NE-1055, NE-7050



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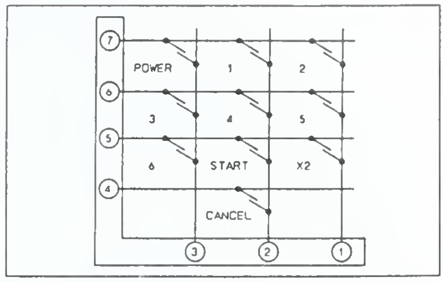
MODEL: NE-1070



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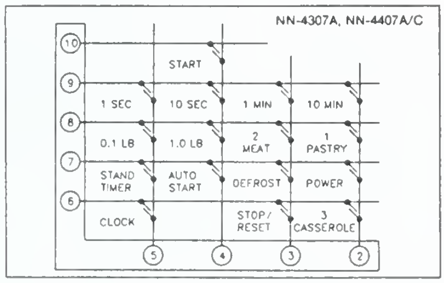

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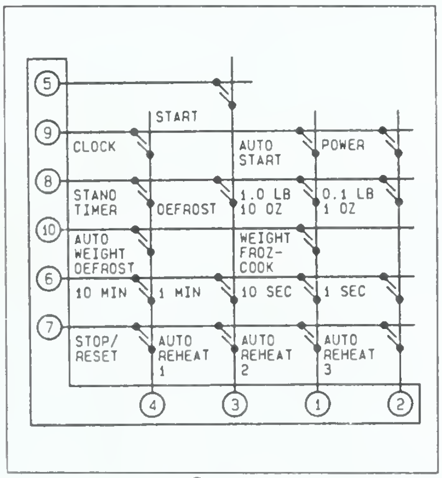
MODELS: NN-4506, NN4506C



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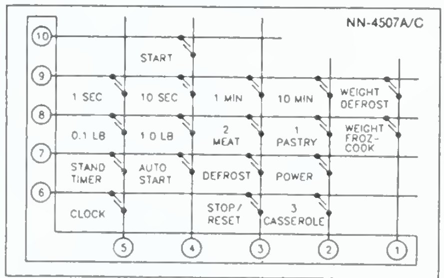

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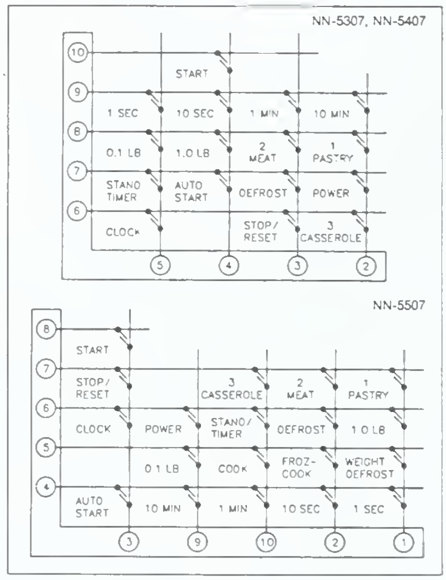

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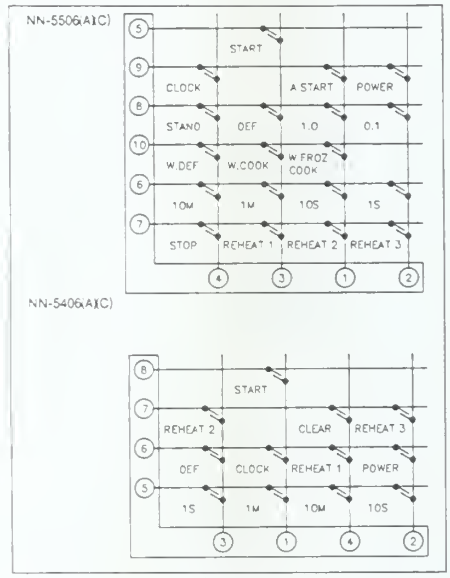

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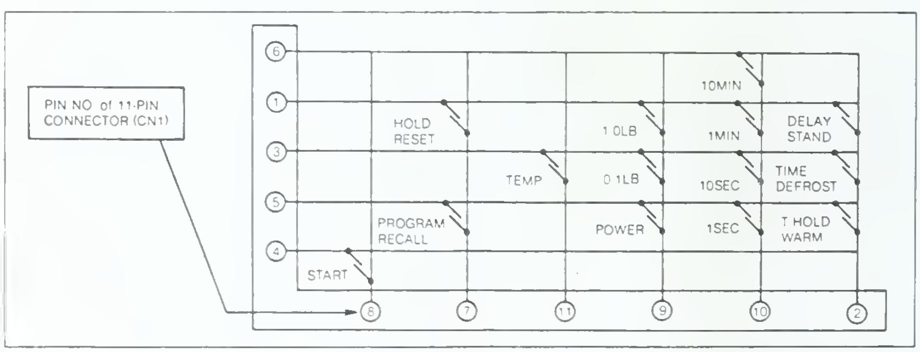
MODEL: MQ5530UW



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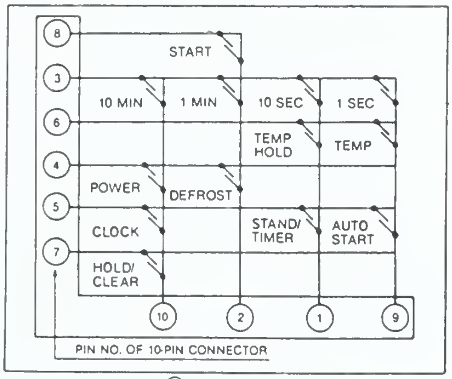
MODELS: MO5540WW, YMQ5540WW



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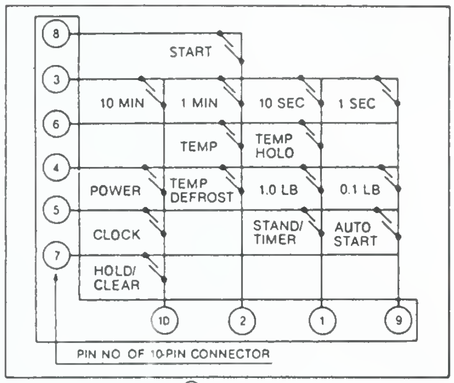
MODELS: MQ5545WW, YMQ5545WW



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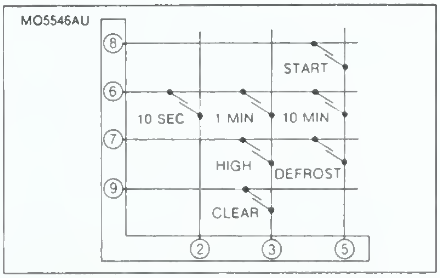

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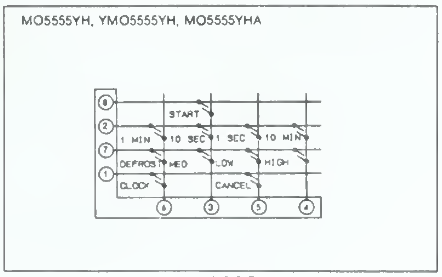

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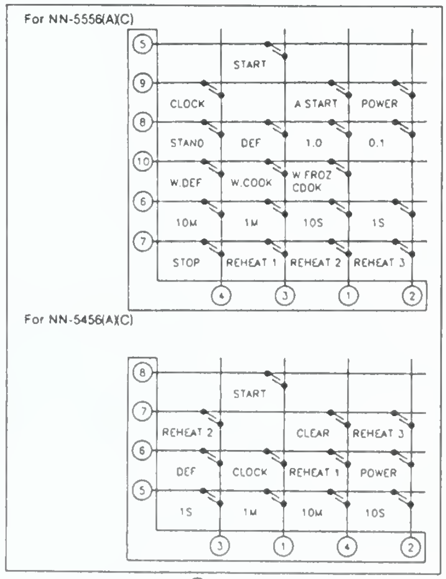

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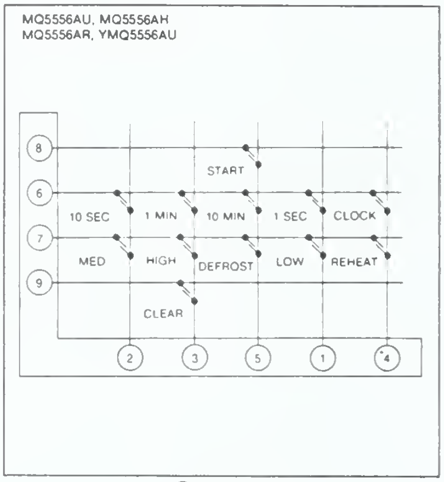

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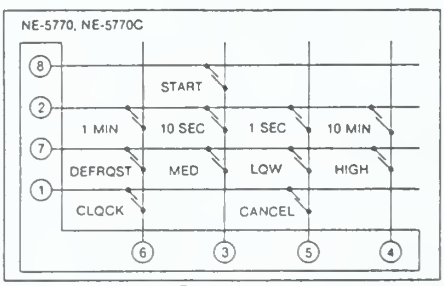

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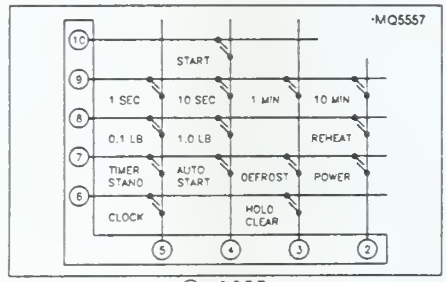

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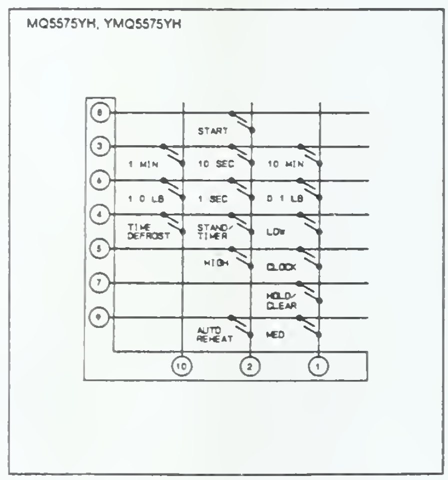

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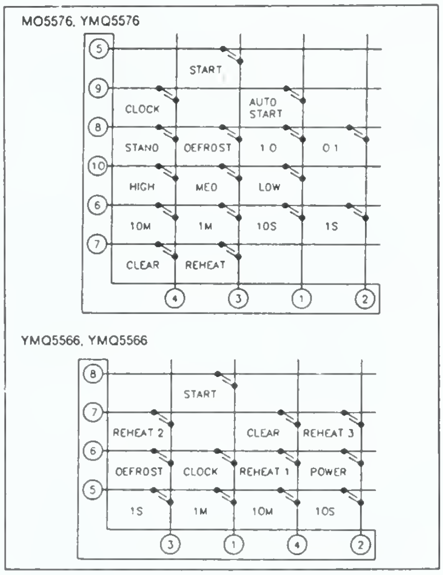

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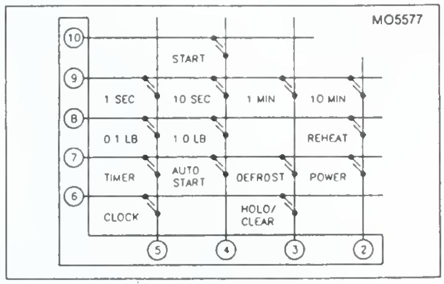

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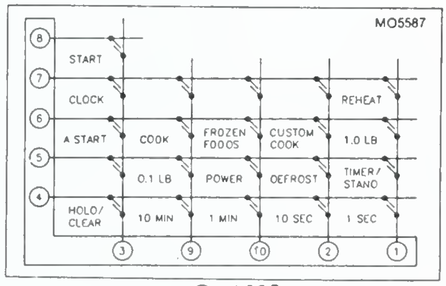

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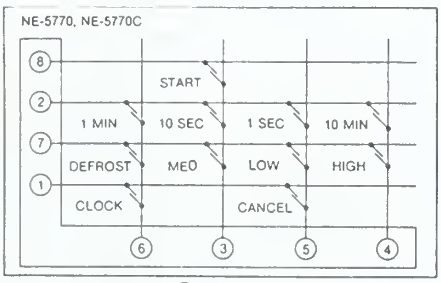

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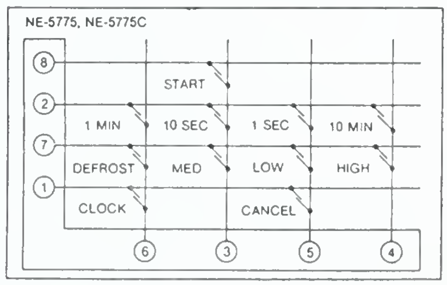

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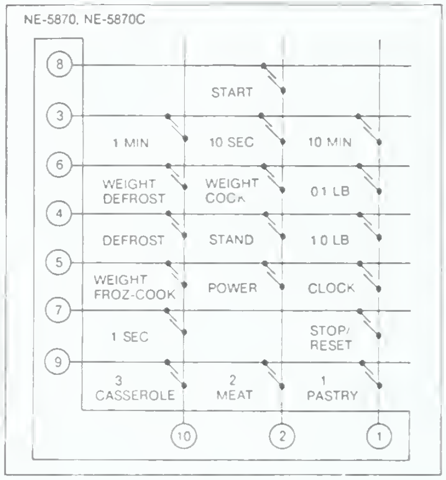

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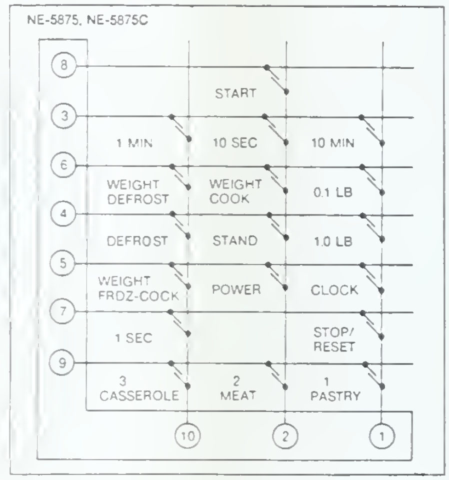

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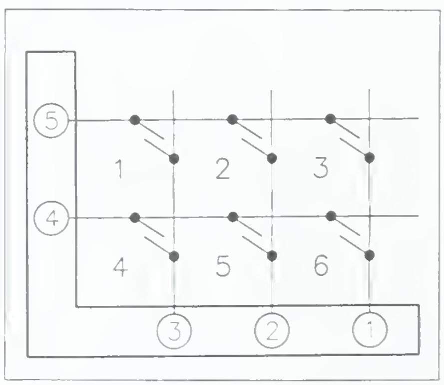
MODELS: NE-6055, NE-6055C



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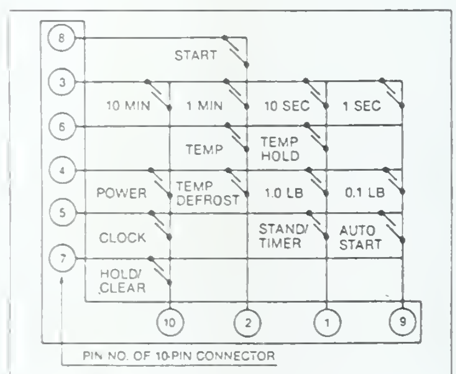
MODELS: MQ6340WW, YMQ6340WW



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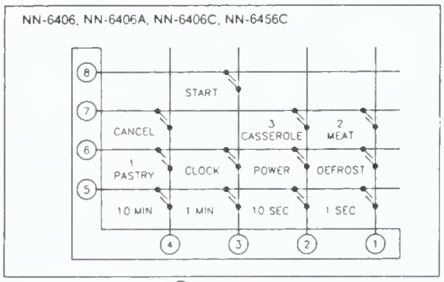

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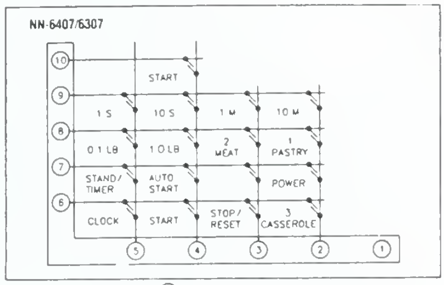

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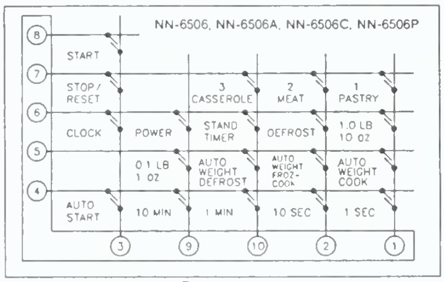

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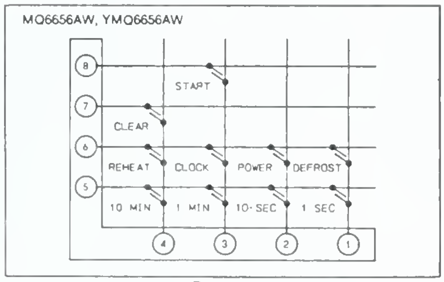

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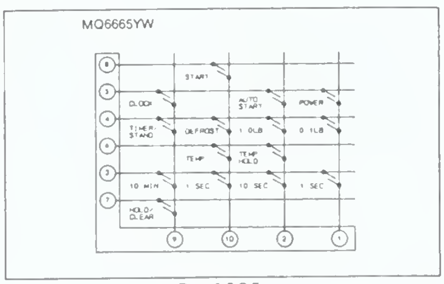

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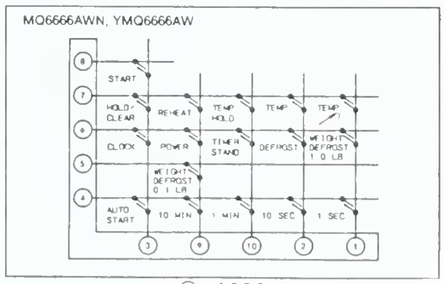

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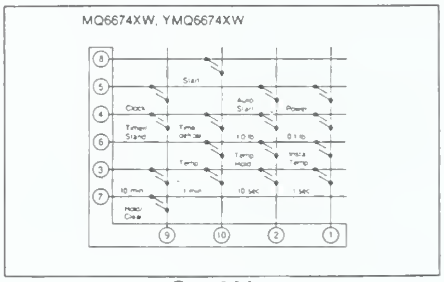

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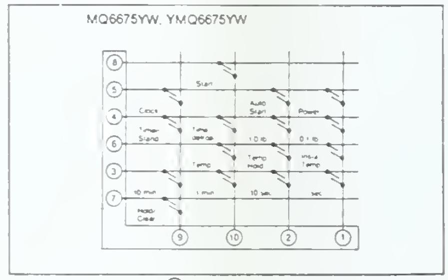

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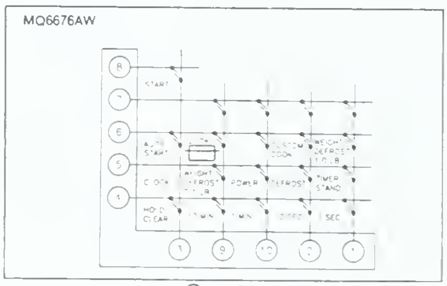

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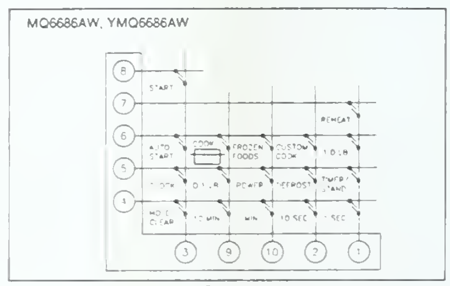

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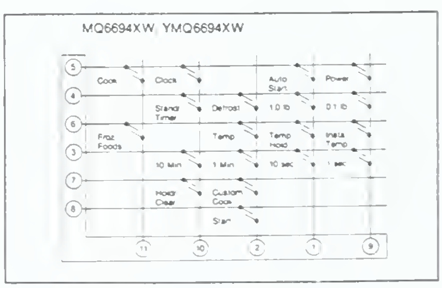

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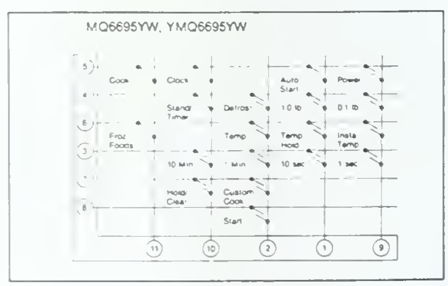

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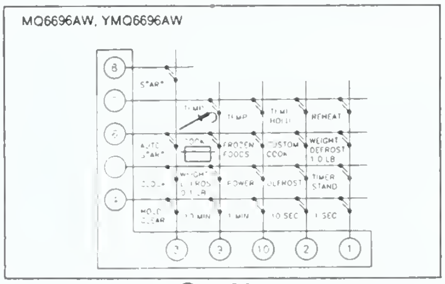

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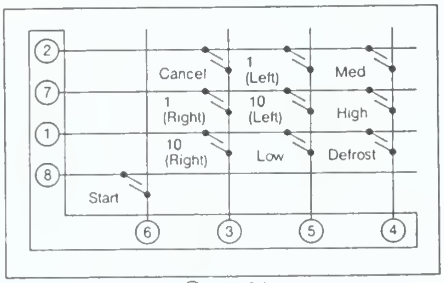
MODELS: NE-6765, NE-6765C



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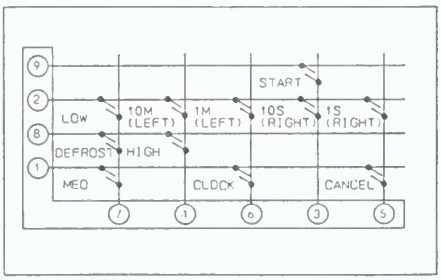
MODELS: NE-6770, NE-6770A, NE-6770C
MODELS: MQ6655YW, YMQ6655YW



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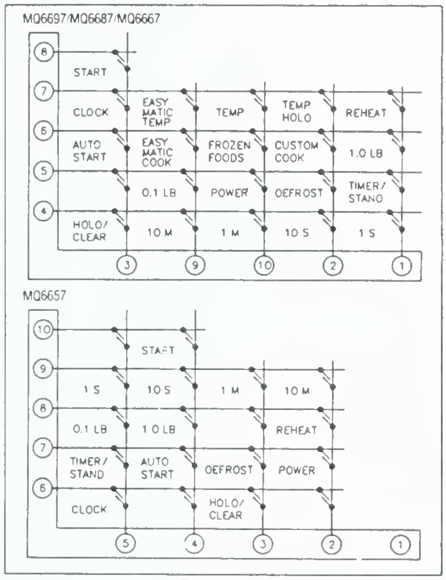

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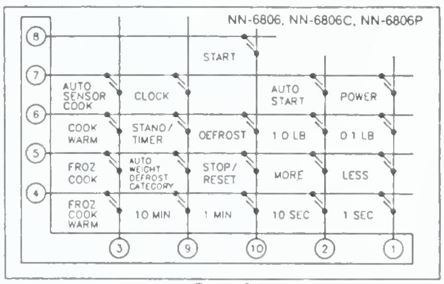

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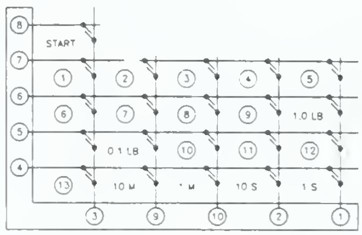
NN-6807/6707/6757/6607/6507/6567



No	NN-6807	NN-6707 NN-6757	NN-6607	NN-6507 NN-6567
1	CLOCK	CLOCK	CLOCK	STOP/RESET
2	COOK-WARM	——	——	——
3	FROZ-COOK-WARM	——	TEMP PROBE	3 CASSEROLE
4	LESS	LESS	TEMP HOLD	2 MEAT
5	——	——	——	1 PASTRY
6	AUTO START	AUTO START	AUTO START	CLOCK
7	A.S. COOK	A.S. COOK	——	POWER
8	FROZ-COOK	——	——	STAND/TIMER
9	MORE	MORE	——	DEFROST
10	POWER	POWER	POWER	CLOCK
11	DEFROST	DEFROST	DEFROST	FROZ-COOK
12	STAND/TIMER	STAND/TIMER	STAND/TIMER	WEIGHT DEF
13	STOP/RESET	STOP/RESET	STOP/RESET	AUTO START

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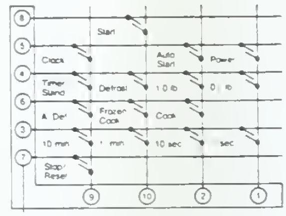
NE-6860, NE-6860C



PIN NO. OF 10-PIN CONNECTOR

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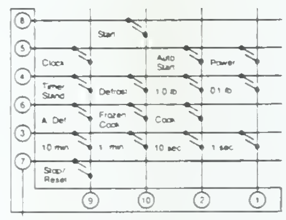
NE-6870, NE-6870C



PIN NO. OF 10-PIN CONNECTOR

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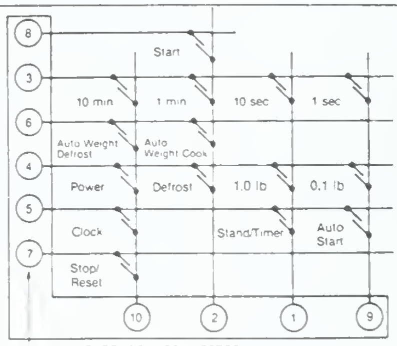
MODELS: NE6850, NE6850C



PIN NO. OF 10-PIN CONNECTOR

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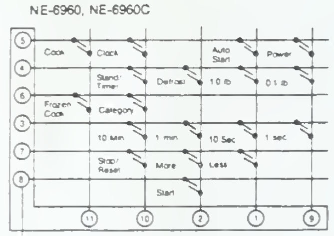
NE-6960, NE-6960C



PIN NO. OF 11-PIN CONNECTOR

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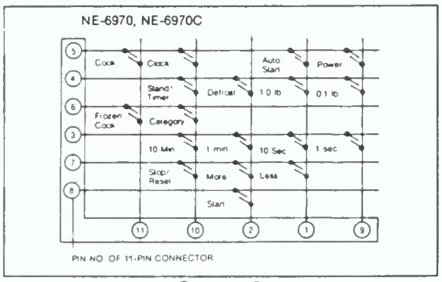

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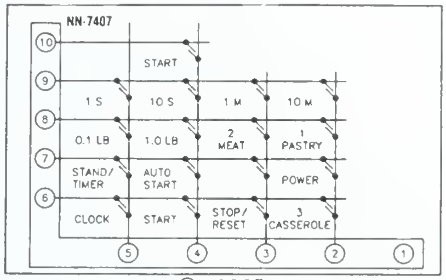

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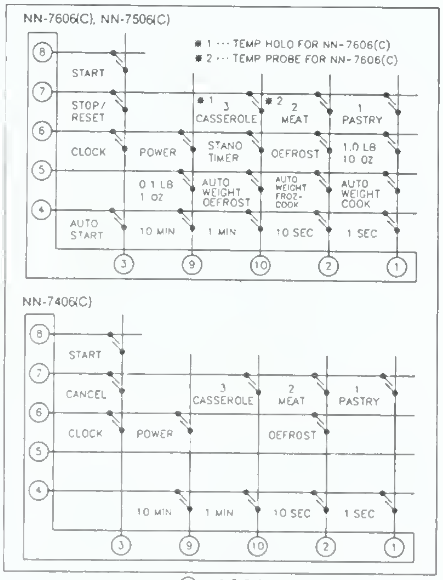

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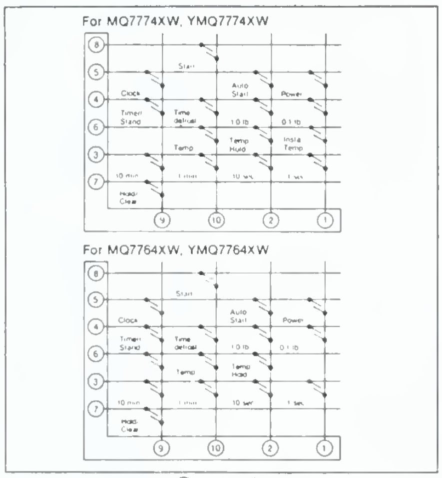

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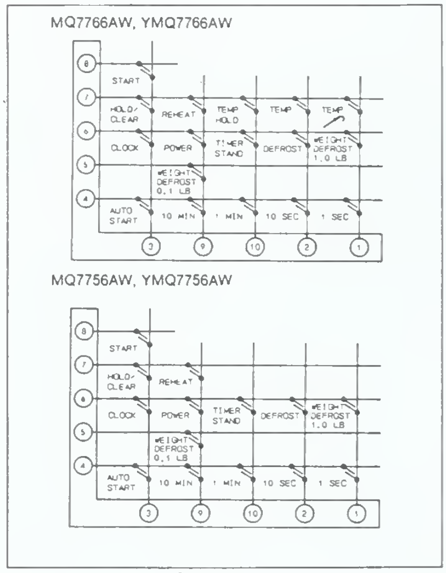

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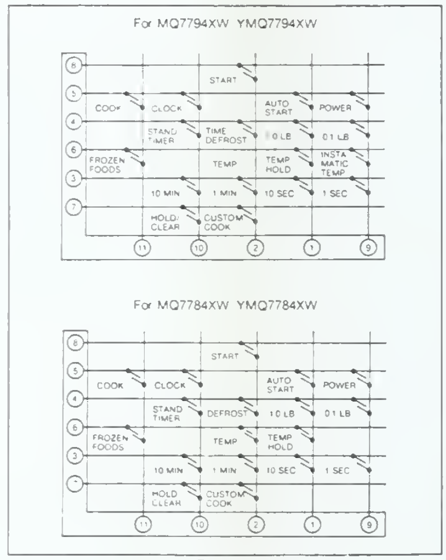

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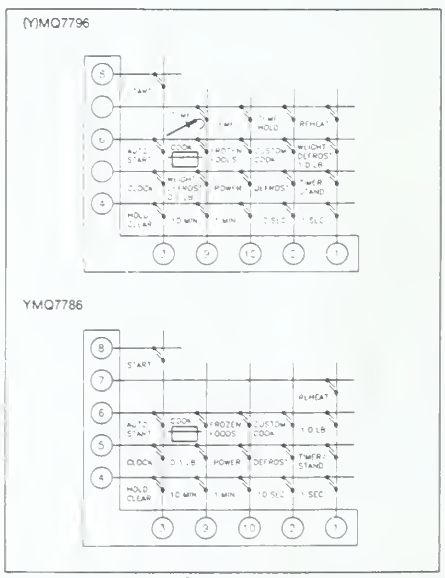

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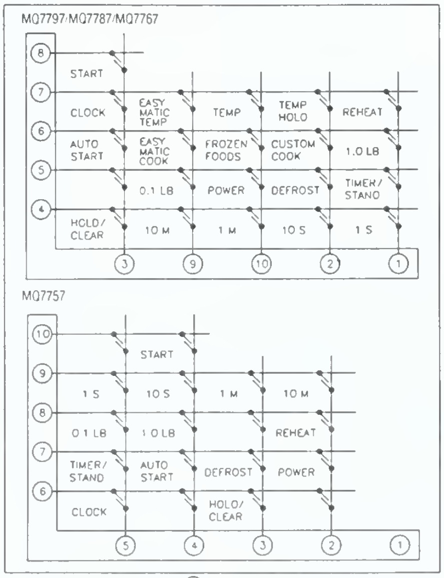

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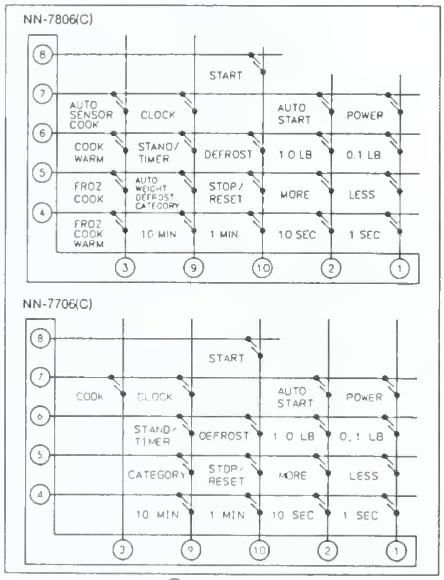

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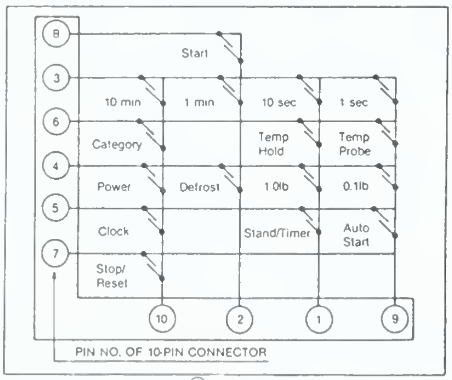
MODELS: NE-7855, NE7855C



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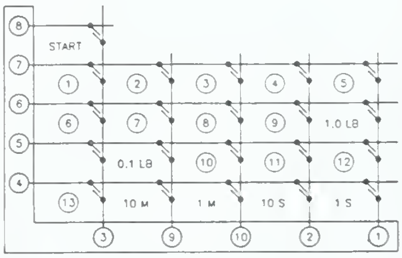
NN-7807/7707/7507



No	NN-7807	NN-7707	NN-7507
1	CLOCK	CLOCK	STOP/RESET
2	COOK-WARM	——	——
3	FROZ-COOK-WARM	——	AUTO REHEAT 3
4	LESS	LESS	AUTO REHEAT 2
5	——	——	AUTO REHEAT 1
6	AUTO START	AUTO START	CLOCK
7	AUTO COOK	AUTO COOK	POWER
8	FROZ-COOK	——	STAND/TIMER
9	MORE	MORE	DEFROST
10	POWER	POWER	AUTO WEIGHT COOK
11	DEFROST	DEFROST	WEIGHT FROZEN COOK
12	STAND/TIMER	STAND TIMER	WEIGHT DEFROST
13	STOP/RESET	STOP RESET	AUTO START

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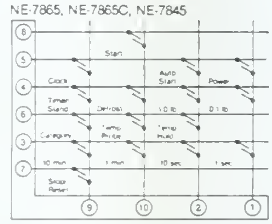
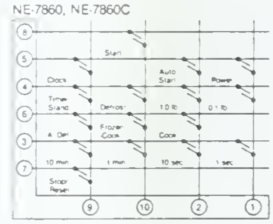
NE-7865, NE-7865C, NE-7845



NE-7860, NE-7860C



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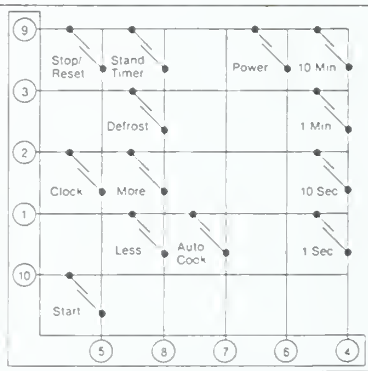
MODELS: NE-7950, NE-7950C



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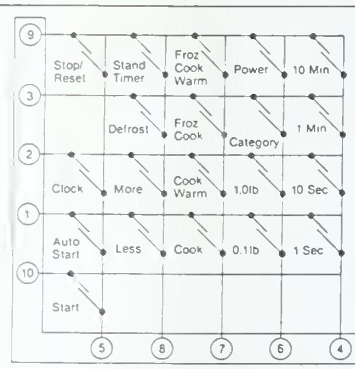
MODELS: NE8050, NE-8050C, NE-8050P



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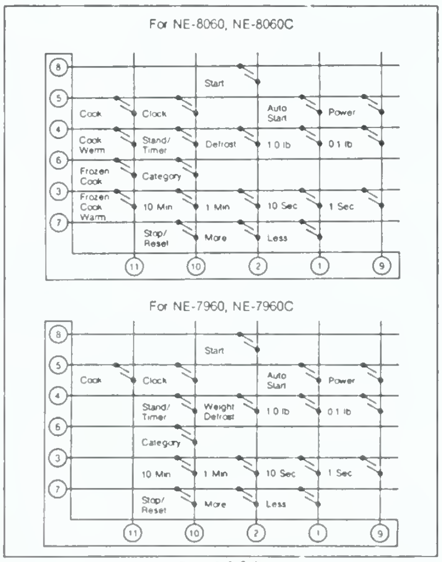

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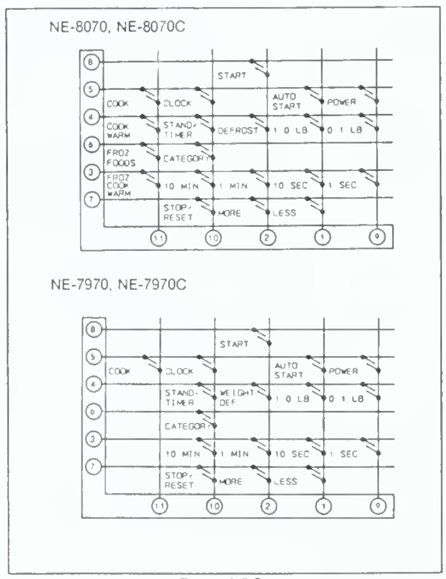

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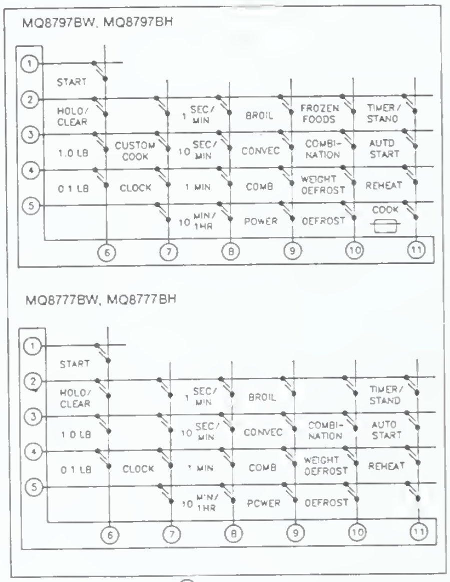

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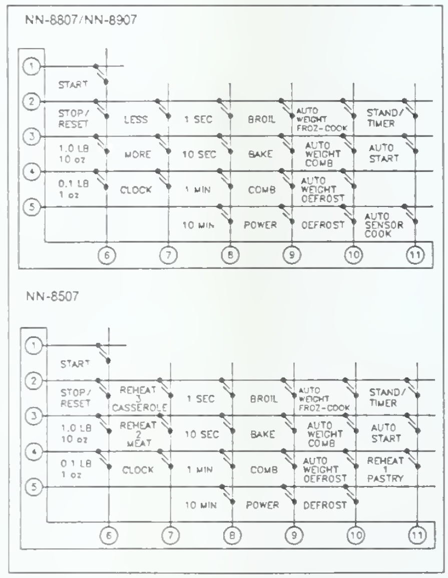

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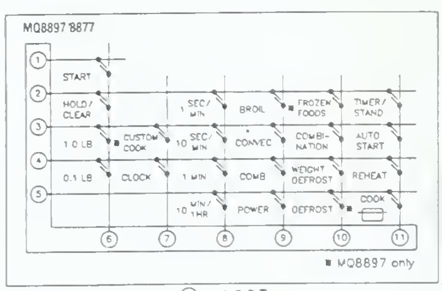

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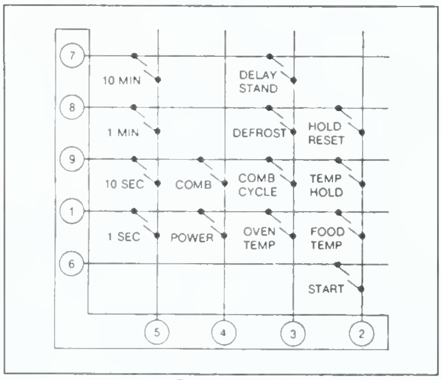
MODEL: MQ8874XW



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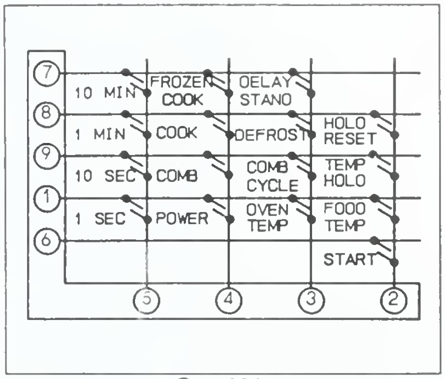
MODEL: MQ8894XW



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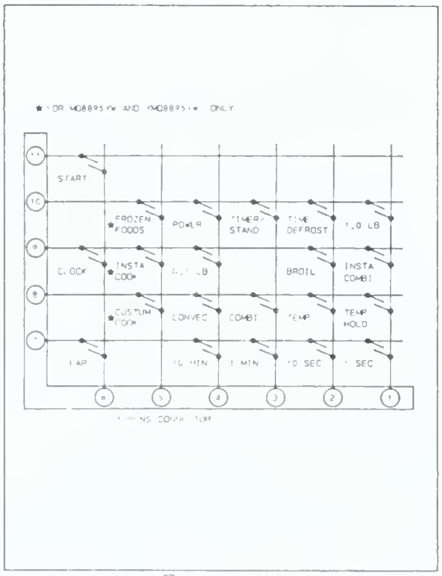

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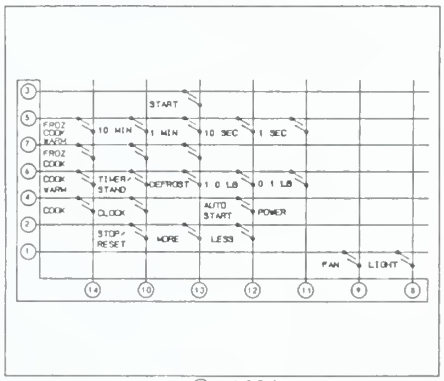
MODELS: NE-8960, NE8960C



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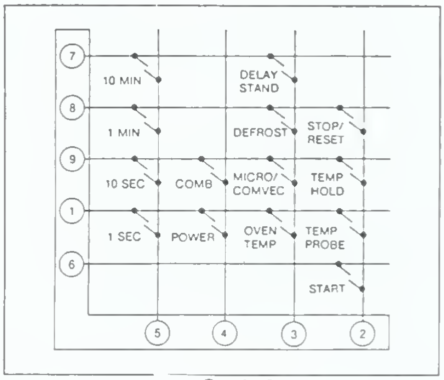
MODEL: NE-9910A



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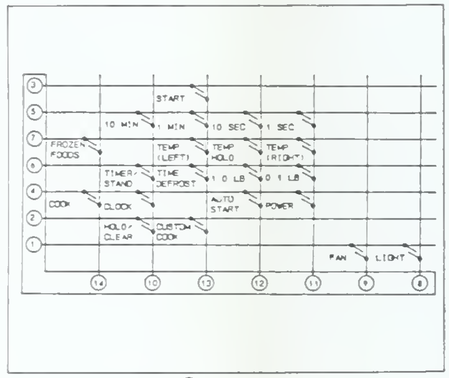
MODELS: MQ9994XW, YMQ9994XW



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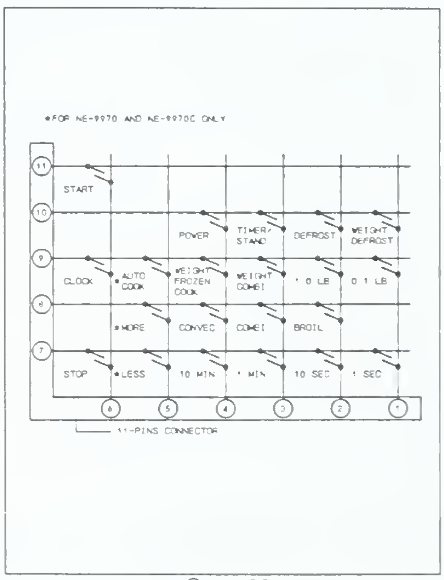

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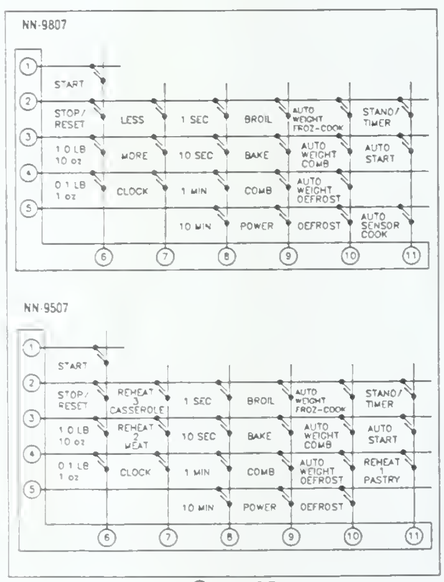

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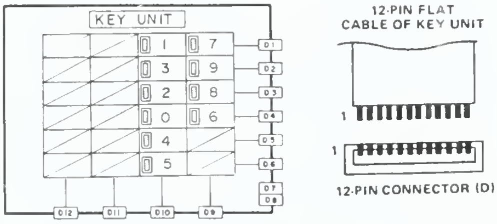
MODEL: R-21BP

KEY UNIT TEST

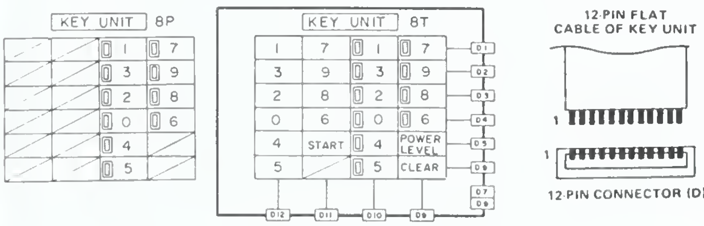
If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the D (12-pin) cable disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit is faulty.
If there is no response, replace the control unit. (The stop switch contacts must be closed.)



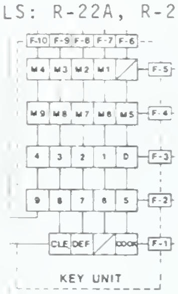
MODELS: R-22BP, R-22BT, R-23BP, R-23BT

KEY UNIT TEST

If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the D (12-pin) cable disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit is faulty.
If there is no response, replace the control unit. (The stop switch contacts must be closed)



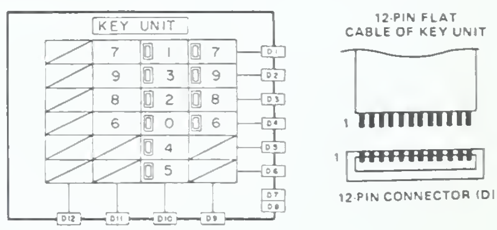
MODELS: R-22A, R-23A



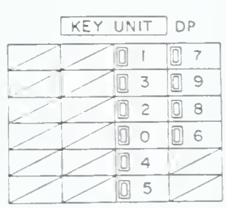
MODEL: R-22BV

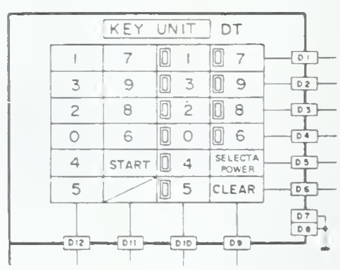
KEY UNIT TEST

If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the D (12-pin) cable disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit is faulty.
If there is no response, replace the control unit. (The stop switch contacts must be closed).

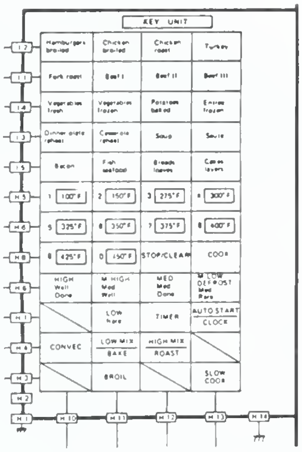


MODELS: R-22DP, R-22DT

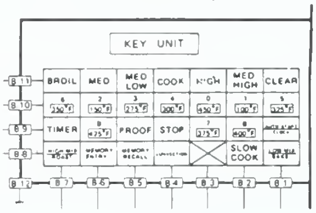




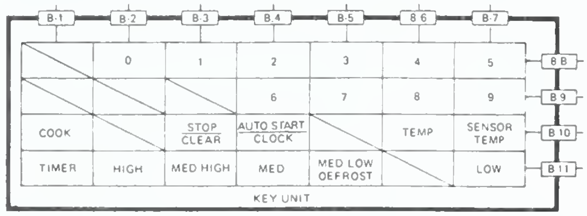
MODELS: R-92HP, R-93RP



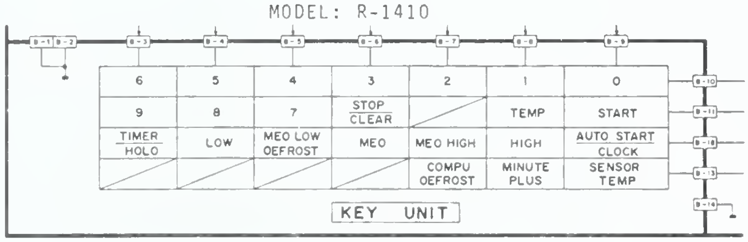
MODELS: R-90HP, R-91RP



MODELS: R-1400, R-1400A



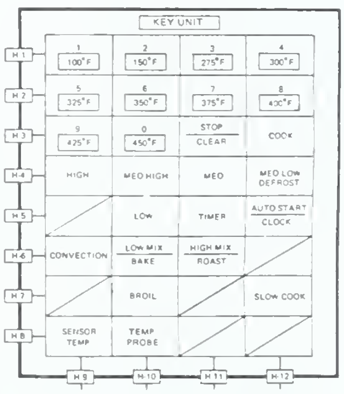
MODEL: R-1410

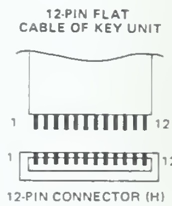


MODELS: R-1800, R-1800A

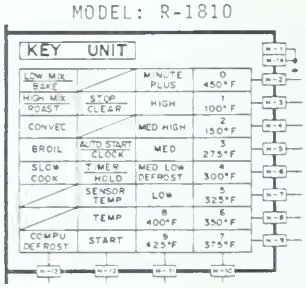
KEY UNIT TEST

If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the H (12-pin) connector disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit is faulty.
If there is no tesponse, replace the control unit.

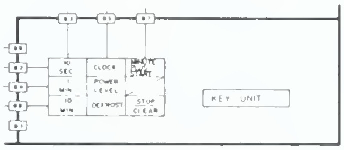




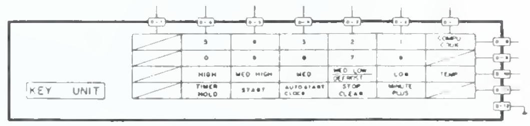
MODEL: R-1810



MODEL: R-2700



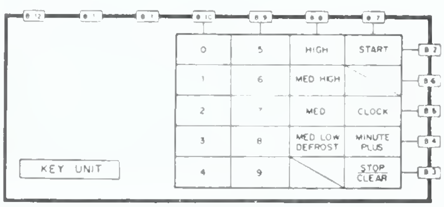
MODEL: R-2730



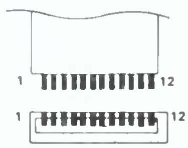
MODEL: R-4260

KEY UNIT TEST

If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the B (12-pin) connector disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit is faulty.
If there is no resopnse, replace the control unit.

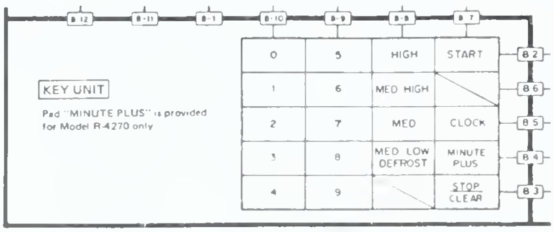


12-PIN FLAT CABLE OF KEY UNIT

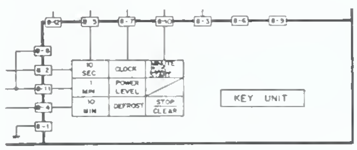


12-PIN CONNECTOR (B)

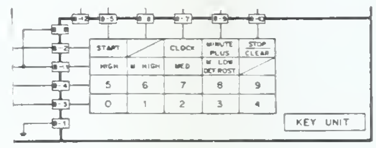
MODELS: R-4265, R-4270



MODEL: R-4275



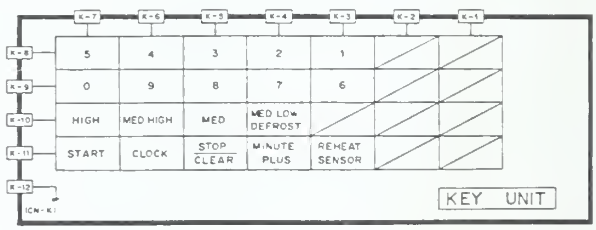
MODEL: R-4280



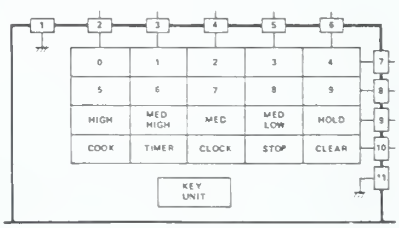
MODEL: R-4670

KEY UNIT TEST

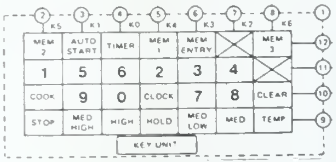
If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the K (12-pin) cable disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit is faulty.
If there is no response, replace the control unit.



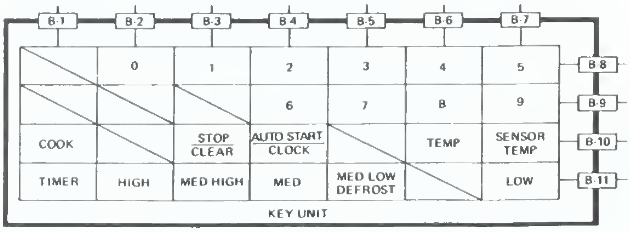
MODEL: R-4810



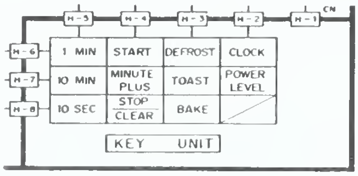
MODELS: R-4820, R-4824



MODELS: R-4840, R-4850



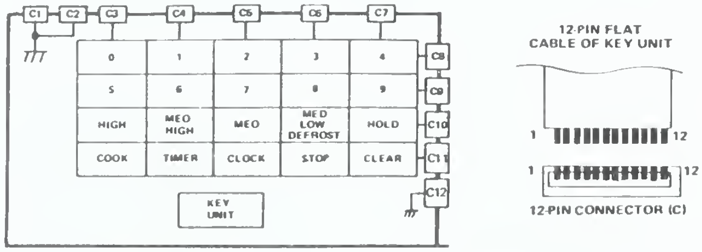
MODELS: R-4980/W, R-4980BK, R-4980AL



MODEL: R-5850

KEY UNIT TEST

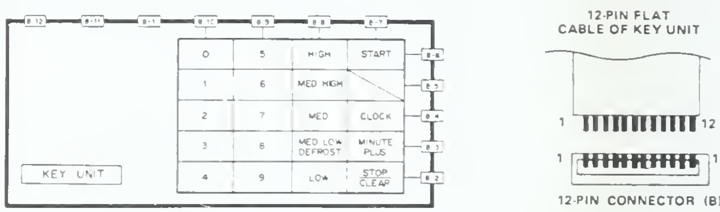
If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the C (12-pin) connector disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit is faulty.
If there is no resopnse, replace the control unit.



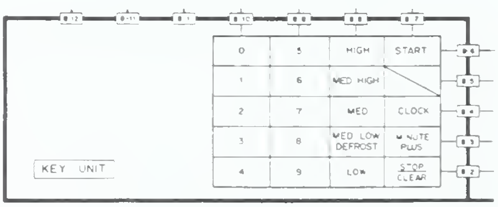
MODELS: R-5960, R-4596

KEY UNIT TEST

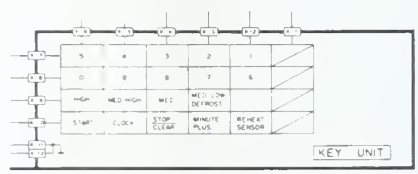
If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the B (12-pin) connector disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit is faulty.
If there is no resopnse, replace the control unit.



MODEL: R-5965

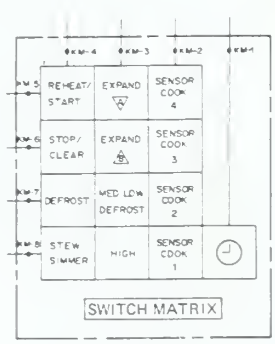


MODEL: R-5970

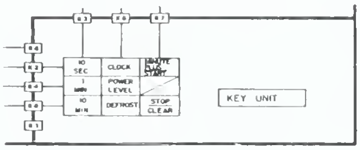


MODEL: R-5977

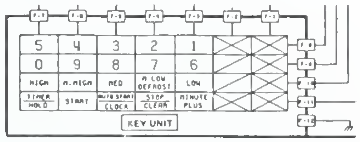
Switch Test
If any indicator does not respond to key operation, short by jumper wire between the pins for that key switch, referring to the following switch matrix.
If the indicator responds and oven goes into operation, that switch is faulty.
If there is no response, replace the control unit.



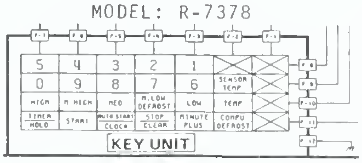
MODEL: R-7180



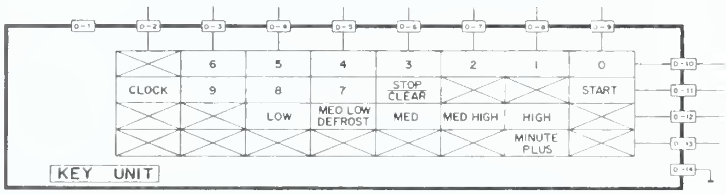
MODEL: R-7273



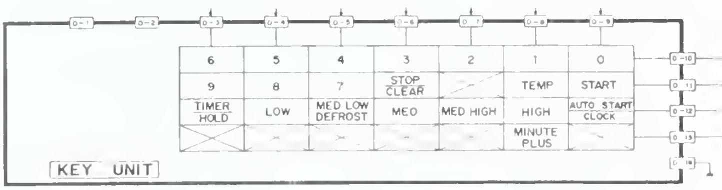
MODEL: R-7378



MODELS: R-7255, R-7260, R-4726, R-7265



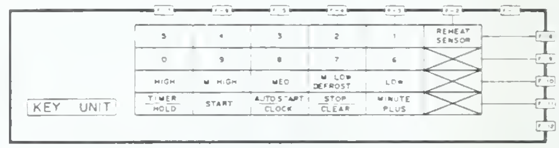
MODEL: R-7360



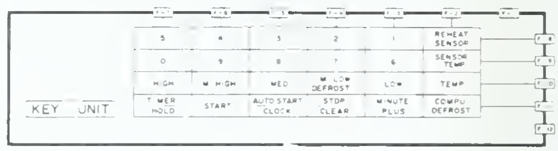
KEY UNIT TEST (R-7270, R-7370)

If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the F (12-pin) cable disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit is faulty.
If there is no response, replace the control unit.

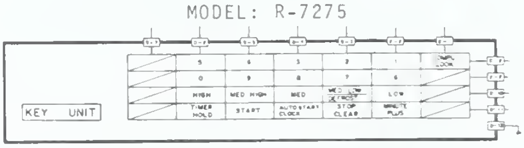
R-7270



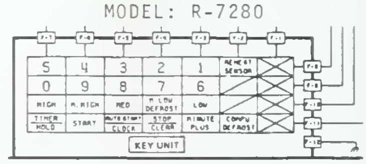
R-7370



MODEL: R-7275



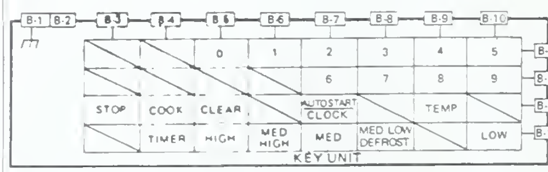
MODEL: R-7280



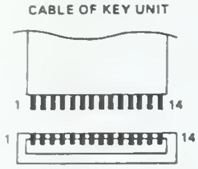
MODEL: R-7350

KEY UNIT TEST

If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the B (14-pin) cable disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit is faulty.
If there is no response, replace the control unit.

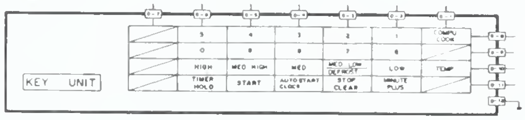


14-PIN FLAT CABLE OF KEY UNIT

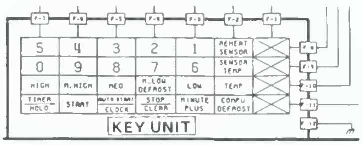


14-PIN CONNECTOR (B)

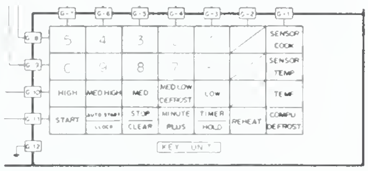
MODEL: R-7375



MODEL: R-7380



MODEL: R-7580



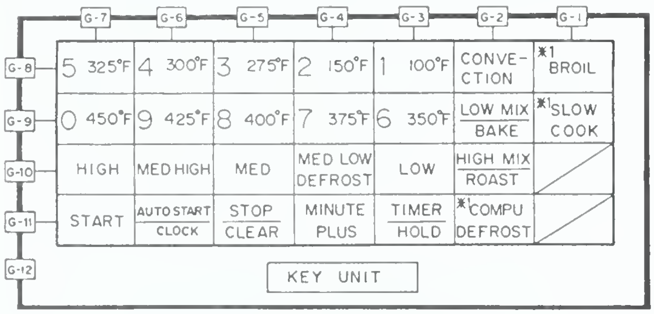
MODELS: R-8165, R-8270

KEY UNIT TEST

When any indicator does not show response against key operation, make short-circuit by jumper wire between the pins for relative key switches for testing, referring to the following key matrix.

If the indicator responds and oven goes into operation, the key unit is faulty

If there is no response, replace the control unit

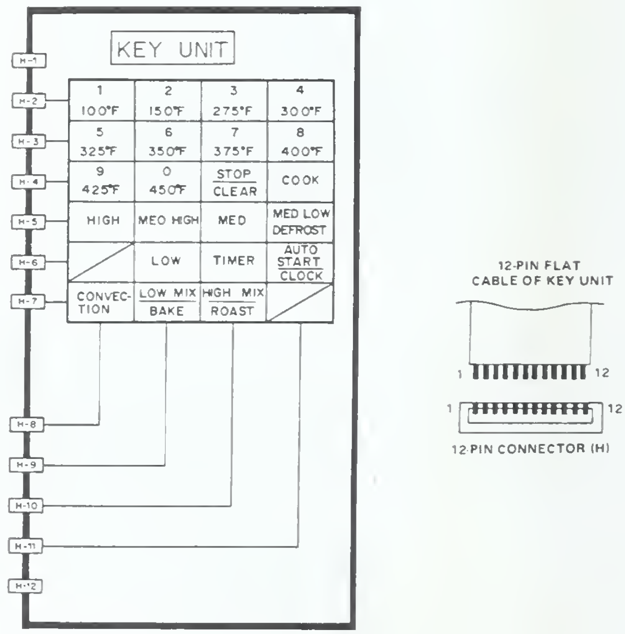


*1 "BROIL","SLOW COOK"··· R8270 ONLY
"COMPU DEFROST"

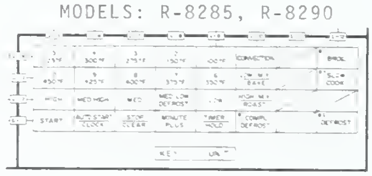
MODEL: R-8260

KEY UNIT TEST

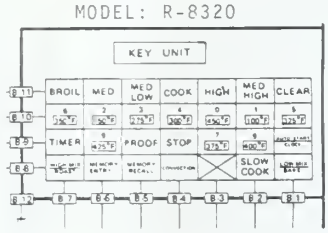
If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the H (12-pin) connector disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit was faulty.
If there is no response, replace the control unit.



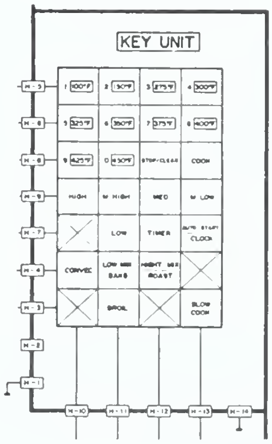
MODELS: R-8285, R-8290



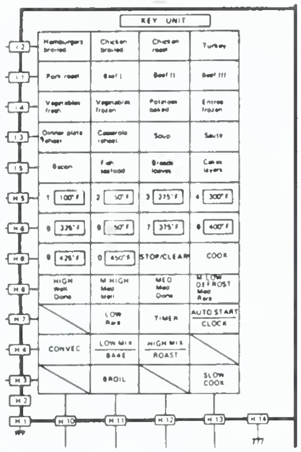
MODEL: R-8320



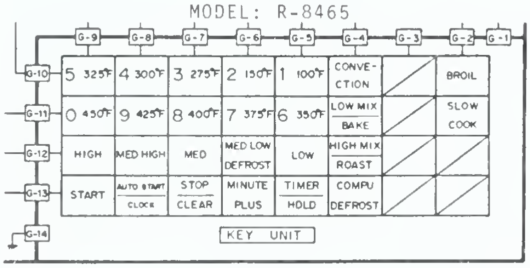
MODEL: R-8330



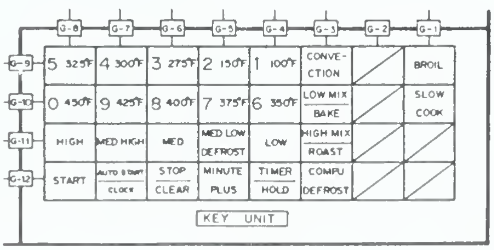
MODEL: R-8350



MODEL: R-8465



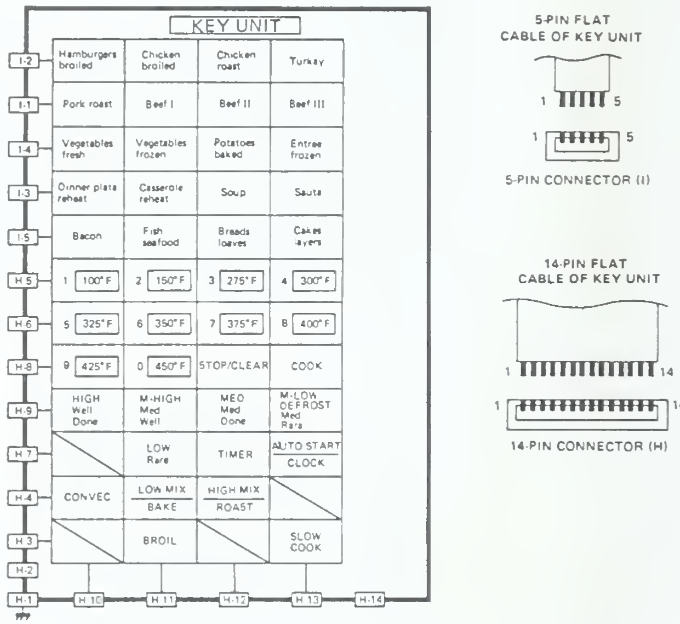
MODEL: R-8475A



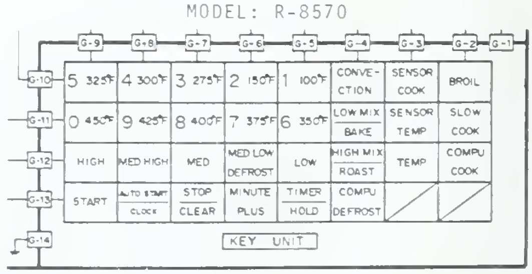
MODEL: R-8340

KEY UNIT TEST

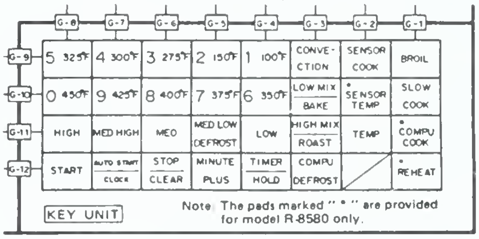
If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the I (5-pin) and H (14-pin) connectors disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit was faulty.
If there is no response, replace the control unit.



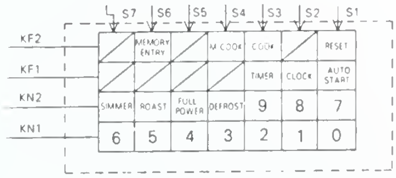
MODEL: R-8570



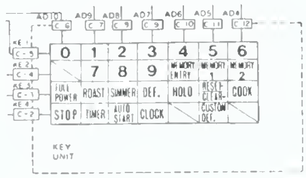
MODELS: R-8575, R-8580A



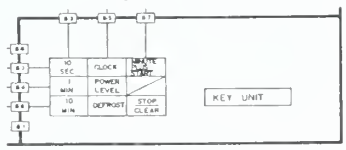
MODEL: R-9200



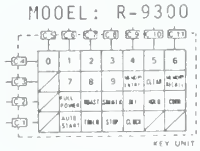
MODEL: R-9210



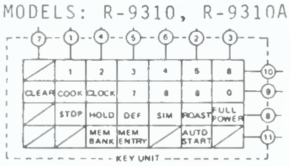
MODEL: R-9280



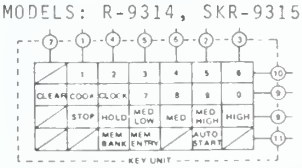
MODEL: R-9300



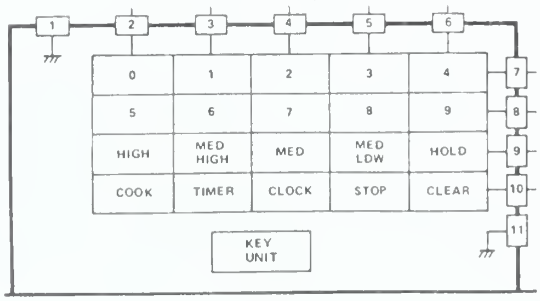
MODELS: R-9310, R-9310A



MODELS: R-9314, SKR-9315



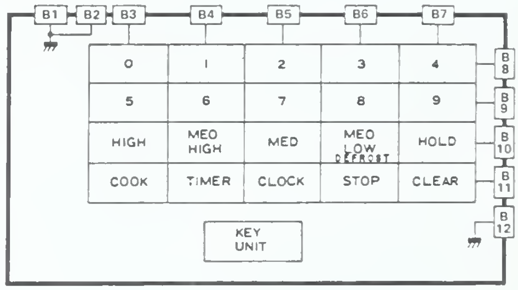
MODELS: R-9330, R-9330A

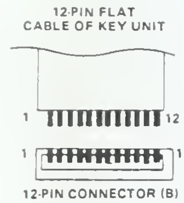


KEY UNIT TEST

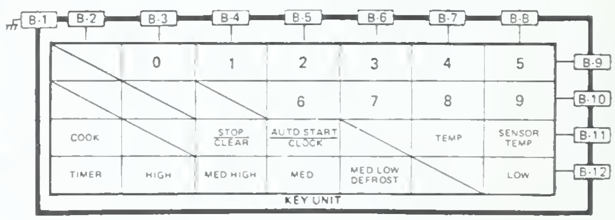
If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the B (12-pin) cable disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit is faulty.
If there is no response, replace the control unit.

R-9350/R-4935

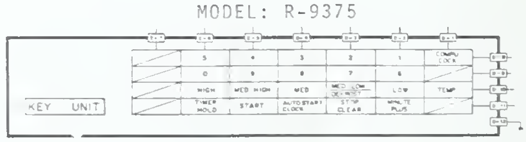




R-9450



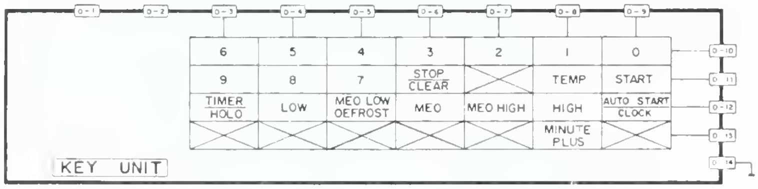
MODEL: R-9375



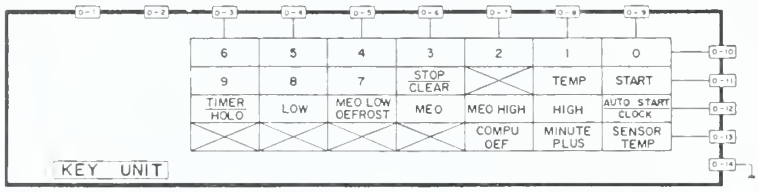
KEY UNIT TEST

If the Indicator does not respond to touching a key Pad use the following matrix and place a jumper wire between the proper pin connections with the D (14-pin) cable disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit is faulty.
If there is no response, replace the control unit.

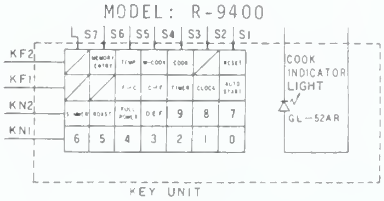
R-9360/R-4936



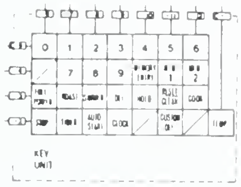
R-9460



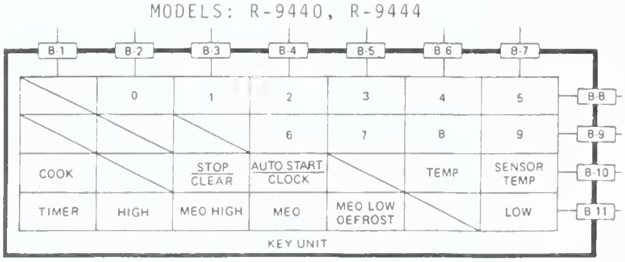
MODEL: R-9400



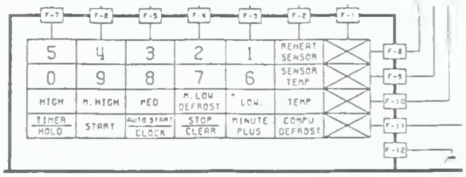
MODEL: R-9410



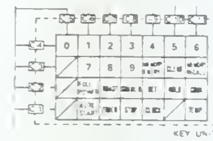
MODELS: R-9440, R-9444



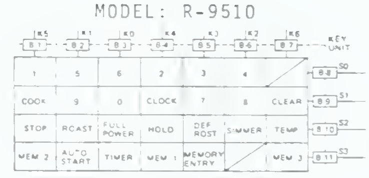
MODEL: R-9480



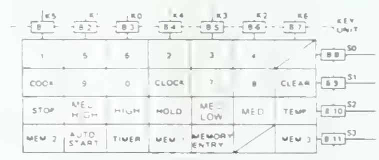
MODELS: R-9500, R-9500U, R-9504, R-9504A, SKR-9505, SKR-9505A



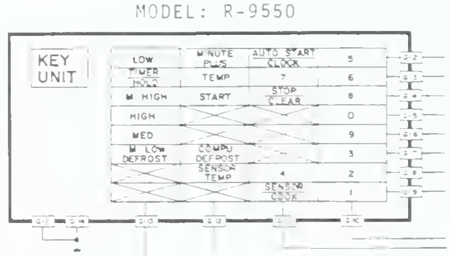
MODEL: R-9510



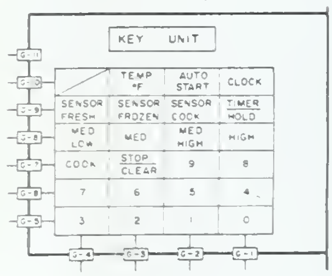
MODELS: R-9520, R-9524, SKR-9525



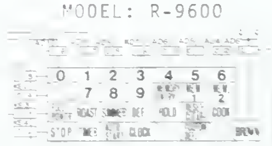
MODEL: R-9550



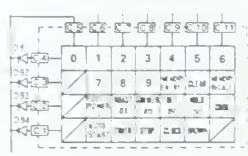
MODEL: R-9560(new &old)



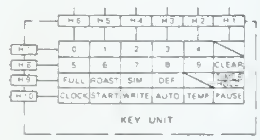
MODEL: R-9600



MODEL: R-9700



MODEL: R-9750

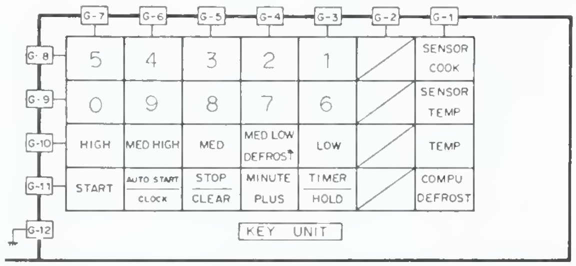


MODEL: R-9570

KEY UNIT TEST

When any indicator does not show response to against key operation, make short-circuit by jumper wire between the pins at relative key switches for testing, referring to the following key matrix

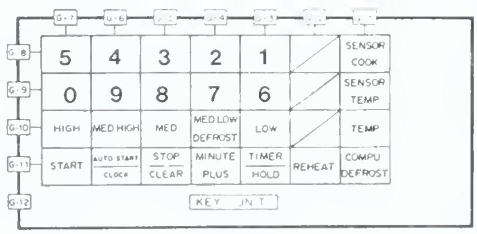
If the indicator responds and oven goes into operation, the key unit is faulty
If there is no response, replace the control unit



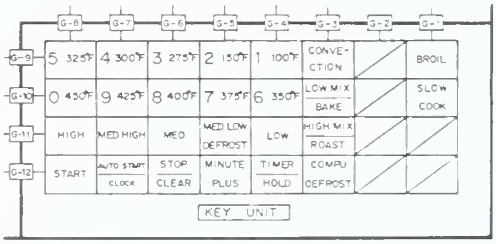
MODEL: R-9580

KEY UNIT TEST

If the indicator does not respond to touching a key pad use the following matrix and place a jumper wire between the proper pin connections making momentary contact with the cable connector disconnected from the control unit.
If the indicator responds and oven goes into operation, the key unit was faulty.
If there is no response, replace the control unit.



MODEL: R-8475



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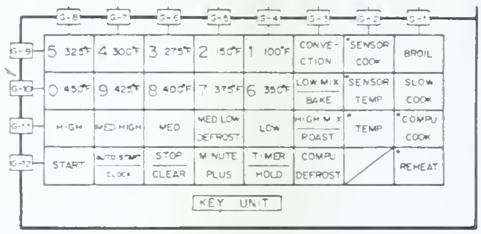
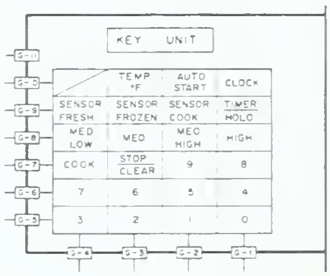
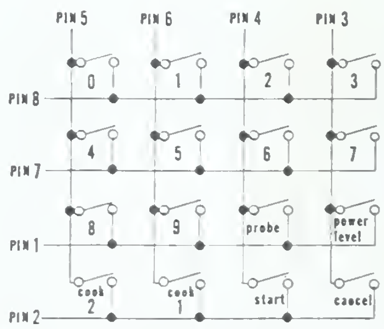


MODEL: R-9530





NOTE: PINS ARE NUMBERED FROM RIGHT TO LEFT WITH FOIL SIDE FACING YOU AND FLEX TAIL STRAIGHT DOWN.

MODELS: 56-0688, 56-1688, 56-3920, 56-4798, 56-4799, 56-480[illegible]
56-4801, 56-4811, 56-4821, 56-5688, 56-8798, 56-88[illegible],
56-8811, 57-2400, 57-2702, 57-6400, 57-6702.

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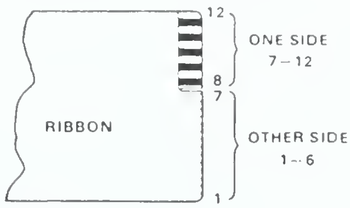
Part of the ribbon connections are on one side and the remainder on the other side. Pad operation can be checked between connections at end of ribbons (use high OHMs scale).



UPPER RIBBON -

PAD	CONN.	PAD	CONN.
Defrost	3-7	4	5-11
Cook 2	3-11	5	4-7
Cook 1	1-8	6	4-8
Min./Sec.	3-8	7	4-9
Probe Cook	2-8	0	5-7
Cancel	2-7	1	5-8
Power Selector	3-10	2	5-9
8	4-10	3	5-10
9	4-11	Start	6-12
Clock		Roast Code	1-7
		Auto Code	2-10
		Cook'N Watch	2-11

LOWER RIBBON -

PAD	CONN.
Light Off	1-6
Light On	2-6
Fan Off	3-6
Fan Low	4-6
Fan High	5-6

MODEL: 56-2896

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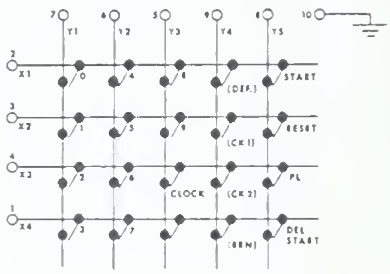
The pins are counted left to right with foil facing you. Pin No. 1 is on the left.

20 KEY MEMBRANE MATRIX



MODELS: 56-4901, 56-8901

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Secrets of Outer Case Removal

Appendix II

It goes without saying that before a microwave oven can be serviced, the cover must be removed. In most cases, the procedure by which to accomplish that is equally as obvious. However, there are models in which, for cosmetic or other reasons, the service entry is not quite as clear-cut. The following directions reveal many of the more obscure procedures that are involved in successfully gaining access to the various components. Hopefully these steps, listed by manufacturer and oven series, will minimize the awkward predicament of having to feign purposeful deliberation while trying to figure out how to get the cover off.

Litton Models—520, 540, 560, D1200, 1560, 1580

These are the large "meal-in-one" residential type units. The outer covers on early-production models were trimmed with a very light-weight metal that was prone to rip at the corners if the cover was removed improperly. This would tend to displease the already leery customer. Replacement trim and that of subsequent models is made from a not-so-easily-ripped stainless steel.

To remove the cover:

1. Unplug the power cord.

2. Slip a flat-bladed screwdriver under the door-release button from its rear side (Fig. II-A), then pry the plastic button up until it can be removed.

3. Remove the mounting screws from the back and along the bottom of each side where the cover wraps around bottom edge.

4. Standing behind the oven, grasp the cover at the lower front corners and gently pull straight back (about an inch) on the cover while pulling the sides out *just enough to clear each bottom edge*—any further will rip the corners of the trim.

5. Without pulling the sides out any further than necessary, lift the case straight up and off of the oven.

6. Reinstall the cover in the reverse order, making sure of the following: that all of the cover locator tabs are properly lined up with the slots in the cover; that air

Figure II-A Pry up the door button

ducting is not wedged between the cover and the cavity front panel; and that metal trim on the cover is aligned with the trim along the bottom.

7. Replace the door button (with a new one if the original is cracked or worn) and reinstall the mounting screws, paying attention to size in relation to original location.

Litton 1000 Series (Includes L-700 Series and D-1100 Series)

These models are the "meal-in-one" successors to those above. The secret here lies in the removal of the door button *and* the bezel which frames it. Each are carefully pried up and out using a flat-bladed screwdriver as follows:

1. After disconnecting the power cord, cover the bezel (plastic frame around the door release button) with cardboard to prevent nicking or marring it.

2. Refer to Figure II-B. Insert the screwdriver (from the back) under the door release button and pull it upward until it "pops" off—it may be necessary to follow its trajectory to avoid losing it.

3. Remove the bezel by pressing its back-side *in* toward the opening left by the button, then lift up about 1/8-inch or until the mounting tabs clear the edge. Do the same to the front side of the bezel, then lift it out and remove it.

4. Pull the cover back slightly to release the mounting brackets from the front panel. Then, while pulling the sides slightly outward, lift the cover up and off.

5. Reinstall the cover in the reverse order, making sure the top- and side-mounting brackets are properly aligned with the front panel. Needless to say, buttons and bezels for these models would be handy items to keep in stock.

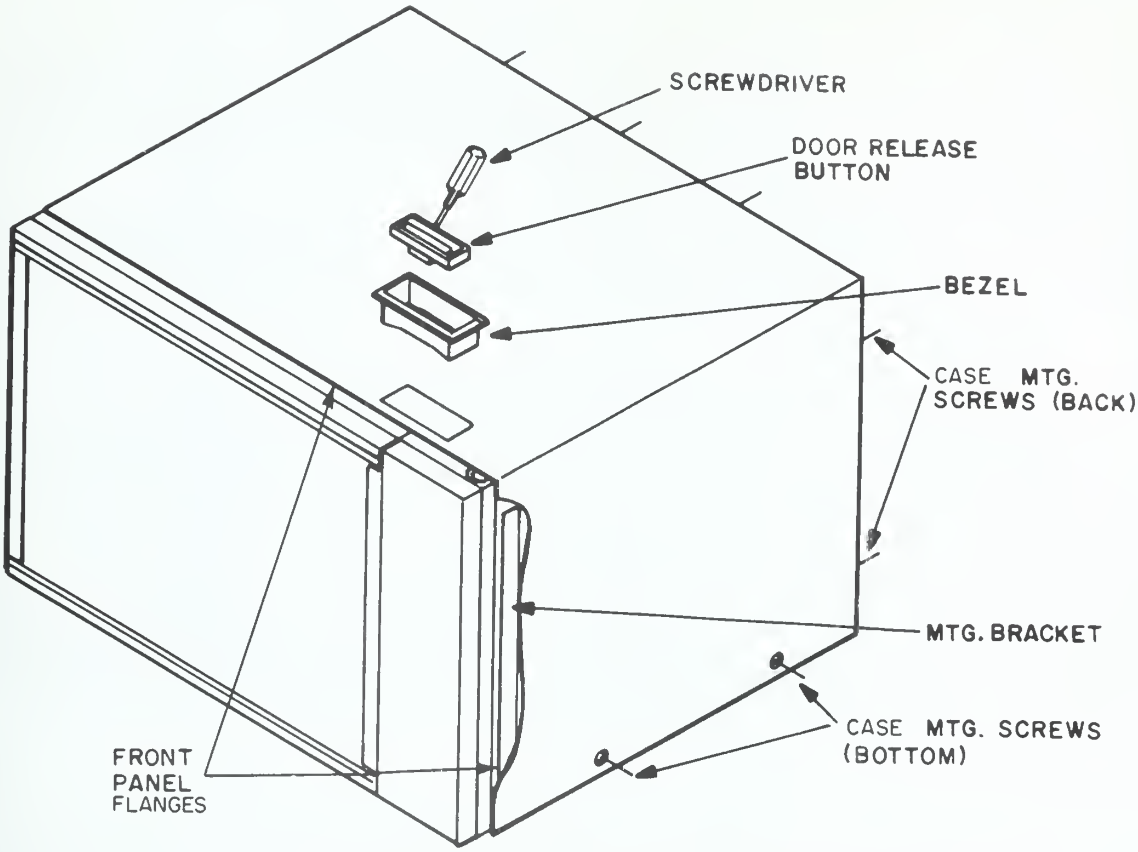

Figure II-B Pry up the button and the bezel (Illustration taken from service literature copyrighted 1981 by Litton Microwave Cooking Products. Used by permission.)

"Little Littons", "Go Anywhere" and *"Quick 'n Easy" Littons,* 1300 and 1400 Series, and Certain Commercial Models of the *FS, VEND,* and *SAND* Series

These units are unique in that the outer case cannot be removed. Service access is gained by removing the front, rear, or bottom access panels as follows:

The front panel (which is the touch panel in some models) is removed by prying in on the right side of the panel frame until the mounting tabs release (painted areas should be protected). Once the right side is free, the panel swings out and the remaining tabs are released.

The rear panel's removal is obvious, as is the bottom access panel. Removal of the bottom access panel is best accomplished with the oven turned upside down. Once the bottom panel is free, any wires that restrict its movement may be disconnected—be sure to note the positions of wires to be disconnected. Also, be careful when reinstalling the bottom panel that no wires are left disconnected, pinched, or touching—the oven is difficult enough to service without any added problems.

Amana RC and *RV Models* (Also Includes Some Older *Amana-Built* Residential Units)

Generally, in these models, access to the high-voltage components is provided through the back as outlined in *Section 13.14.* And, as discussed under the *"Panel Interlock Switch"* heading of *Section 9.6,* many of the control components can be reached through the front. However, service access to many other components requires the removal of the oven cavity.

1. Unplug the oven and remove the rear cover.

2. After the rear cover is removed, an additional screw must be removed from the back. The hexhead screw is located near the top right-hand side, facing the back of the unit. It secures the outer case to the waveguide flange.

3. DISCHARGE THE HIGH-VOLTAGE CAPACITORS, AND THE BY-PASS (RF) CAPACITORS.

4. Remove the two bolts that secure the filament transformer (as well as the mounting plate) to the floor of the outer shell. Then, in applicable models, raise the component mounting plate in order to reach and remove the hexhead screw that secures the stainless steel cavity flange to a support tab on the floor of the outer shell.

5. Locate and remove the one or two more hexhead screws that secure the oven cavity to the base assembly of the high-voltage transformer.

6. The cavity is now ready to slide out through the front of the outer shell as shown in Figure II–C. This may take some prying to separate surfaces that have long been held fast by dried grease. Once separated, at this point, only a limited amount of forward travel may be achieved due to restrictive wiring.

7. To remove the cavity completely, which is required in order to reach many of the control and protection components, all of the restrictive wiring must be disconnected. (Including carefully removing the magnetron leads after **discharging the feed-through capacitors** by shorting each terminal to ground.) Pay attention to the wiring arrangement to avoid miswiring when the unit is reassembled. And, beware of sharp, unforgiving edges.

Hobart

To remove the stainless steel cover, the right- and left-hand control panel endcaps must first be taken off. Do this by removing from each end cap the two truss-head screws, then lifting away the cap. Four similar screws along the lower back side must then also be removed. The cover may then be slipped back, up, and off of the chassis. Notice on the right-hand endcap there is a stud with a bumper attached—this activates an interlock switch, and so must be fitted in place in order to operate the oven with the cover off.

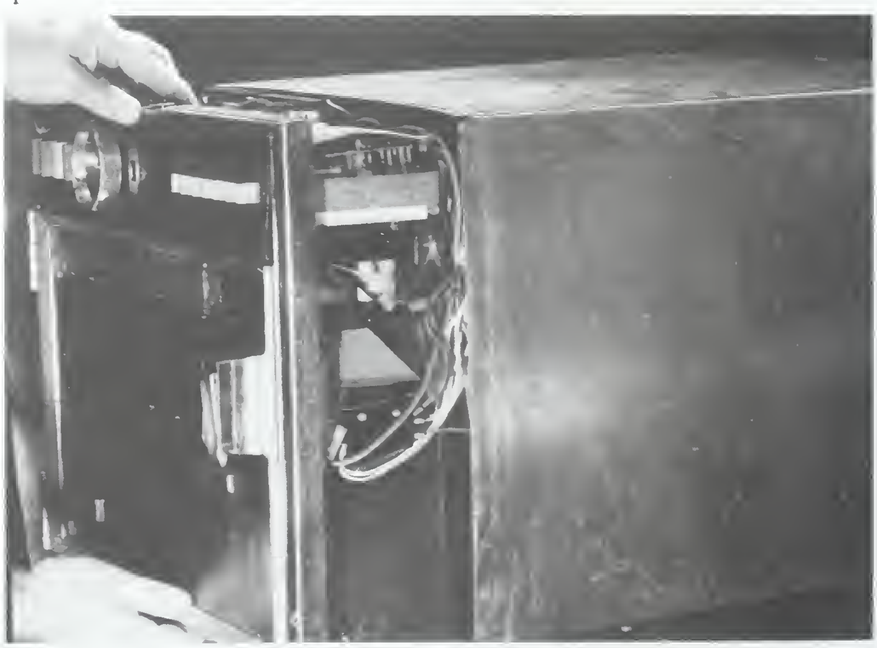

Figure II–C Slide out the cavity

Microwave Cooking Techniques

Appendix III

It is expected that a competent servicer should be capable of restoring an ailing microwave oven to its proper working condition. It is impressive, though, when that servicer is also well-informed on the various techniques of microwave cooking and can offer suggestions on how to obtain the best results. Included here are some basic techniques and principles of microwave cooking.

Time or Temperature

The decision to cook by time or temperature is determined by the product itself. When the internal temperature of an item is an accurate indication of how well it is cooked, such as a turkey, a tender roast, or certain beverages, use the temperature probe. When the taste, texture, or visual appearance is the factor, such as a baked potato, cake products, or sauces, use the timer.

Cooking by Time

The length of cooking time required depends on a number of factors: the quantity, density, sensitivity, and starting temperature of the food. The shape of the food, the type of utensil used, and the altitude must also be considered. When uncertain, a good rule of thumb is to **set the timer for a minimum amount of time, then check frequently for doneness. If necessary, add more time in small increments.** It is better to undercook than overcook. Also, bear in mind that residual thermal heat within the food causes additional cooking to occur after the food is removed from the oven. So, in determining cooking times, allow for this additional cooking. Further, in connection with the quantity of food, the amount of cooking time required increases as the amount of food to be cooked increases. However, the time increase is not necessarily proportional to the food increase. It is therefore suggested, unless the oven is designed to accommodate "meal-in-one" cooking, that two separate dishes be prepared and cooked separately.

Generally speaking, the time to microwave an item may be 1/4 to 1/3 of the time

required to cook the item by conventional means. This will vary though, due to the pronounced effect that microwaves have on certain food characteristics. For example, microwaves, like many of us, are attracted by sugar, so the high-sugar-content jelly in the center of a jelly doughnut will heat up much faster and to a higher degree than its less-sugary surroundings. Water too attracts microwaves, which accounts for the fact that a product with low moisture content like popcorn turns to "flop-corn" in a microwave oven (some commercially packaged microwave popcorn, and popcorn popped in microwave-approved popcorn poppers bring reasonably satisfactory results). The fact that fat also attracts microwaves partially dispels the old myth that foods do not brown in a microwave oven. Foods with a high fat content, like bacon, turkey, chicken, or roast, will brown during prolonged cooking, as their natural fats are drawn to the surface. The food's surface browns in its own sizzling fats. Smaller portions of meat, like steaks or chops do not brown because they cook before the browning can take place. Further considerations in cooking meat involve the use of salt. Salt draws moisture from meat during microwave cooking, which tends to toughen the outer layer of the meat. Therefore, for best results, add salt *after* the meat is cooked. Other seasonings, such as pepper or paprika, do not have the same effect and thus can be used prior to cooking.

Cooking by Temperature

The temperature probe is a sensitive device and requires the proper use and care, as well as the proper placement and positioning in the food so as not to give inaccurate readings. Following are some guidelines regarding the use and care of the temperature probe:

1. It is easier to position the probe properly while the food is on the outside of the oven. Insert the probe to about two-thirds of its length into the food (check that the first ½-inch of the sensor is in the densest part of the food), then place the food into the oven, and be sure to securely insert the plug into the receptacle.

2. If the recipe calls for the food to be covered while cooking, use clear plastic wrap to cover the food and insert the probe through the plastic wrap.

3. While the probe is immersible, it should not be soaked. Carefully wash it in warm water with a mild detergent, then wipe it dry.

4. Do not wash the probe in a dishwasher.

5. Do not attempt to insert the probe into frozen food, unless the following preparations have been made: Before the food is frozen, insert a straw deep into the thickest part of the meat. When the food is frozen the straw will form a channel into which the probe can be inserted. The food can then be defrosted and cooked without the need to return to the oven to insert the probe after the food thaws. This does not apply to prefrozen food. Prefrozen food must be defrosted completely before inserting the probe.

6. Do not let the probe cable rest on or in the food, against the interior walls, bottom, or door while in operation.

7. Do not substitute the original probe for another one unless you are certain of its compatibility.

8. Do not leave the probe inside the oven while not in use. This eliminates the possibility of damaging both probe and oven by operating the oven with only the probe inside.

9. Do not use the cable to remove or insert the probe or the plug. Use the handles.

10. Do not use the probe in either a conventional stove or a convection oven.

Proper placement of the probe:

11. When cooking more than one item, place the probe sensor into the densest food item.

12. Poultry—Insert the sensor into the thickest part of the breast meat. Due to the many variables in cooking a bird, the probe's indications should be augmented by conventional methods as well. This will ensure an accurate measure of doneness.

13. Casseroles, Soups, Beverages—Place the probe sensor into the middle of the item.

14. Leftovers—insert the probe sensor into the largest, or densest, part of the food.

15. Seafood—Place the sensor into the thickest part of lobster and into the center of fish.

16. Bone-in Meats—Place the tip of the probe into the meatiest area of the cut. Keep the probe away from bone, marrow, or pockets of fat, which reach different temperatures than the surrounding meat and will give inaccurate readings.

17. Boneless Meat—Either insert the probe into the meat from the end and push toward the center, or angle the probe in so that it is supported by the meat with the tip in the center.

18. Canned Vegetables—Place the probe in the center with the tip (sensor) in the middle of the product. Vegetables are, of course, first removed from metal cans.

19. Baked Goods—Generally, place the first ½-inch of the sensor into the center of the item. Remember that fillings with a high sugar content will heat faster than the cake portion.

20. Thick Sandwiches—Insert the probe sensor into the thickest part of the sandwich.

The following information is a general reference, outlining the relationship between the internal temperatures and the actual degree of doneness of various food products when they have finished cooking. The individual service manual or cookbook should be consulted for more specific information.

Beef
Rare .... 120°F
Medium .... 135°F
Well .... 150°F

Lamb
Medium .... 135°F
Well .... 150°F

Chicken or Turkey
Whole or parts .... 175°F

Pork
Precooked Ham .... 130°F
Fresh Ham .... 175°F
Loin Roast .... 175°F
Tenderloin .... 175°F

Variable Power Cooking

In order to obtain satisfactory cooking results when using the variable power feature, an appropriate cooking speed must be selected for each type of food. Some delicate foods require more gentle cooking, while other more dense food products

require a slower cooking speed so outer surface heat has time to penetrate to the center. Following are a few basic examples with the recommended power level:

WARM (about 10% power) for softening cheese or butter, raising bread, or holding food warm.

LOW (about 20% power) for small amounts of food that must be cooked slowly such as clarifying butter or softening chocolate (which is sensitive to microwave energy). Also for warming such items as pancakes, tacos, or tortillas.

DEFROST (about 33% power) for thawing frozen foods of all types.

MEDIUM LOW (about 40% power) for convenience food items such as cakes and pies, and the slow cooking of less tender cuts of meat.

MEDIUM (about 50% power) for stews and soups, and to start items such as muffins or cornbread.

MEDIUM HIGH (about 60% power) for roasts, hams, and meatloaves. Also for sensitive foods, such as sour cream, oysters, eggs, and mushrooms, which can overcook very quickly.

REHEAT (about 73% power) for reheating leftovers and precooked items.

HIGH (100% power) for vegetables, fish, and heating beverages.

Additional Cautions About Microwave Cooking

Do not attempt to reheat or cook eggs while still in the shell—they will very likely EXPLODE! On one occasion, while a young man was removing an egg from the oven, it exploded sending projectiles of fragmented shell in every direction, one of which lodged in his eye like shrapnel. It had to be removed by an eye specialist. If left inside the sealed shell, internal pressure will build up until the egg explodes like a firecracker. Do not even *reheat* eggs unless they are scrambled or chopped. The yoke, too, should be punctured before cooking. Exploding eggs have been known to blow off oven doors and blow holes in cavity shelves or trays. Even poached eggs have been known to explode. Wait at least one minute before cutting into a poached egg.

To prevent bursting, pierce the skin of naturally sealed (nonporous) items like whole potatoes, hot dogs, apples, acorn squash, and sausage. The sealed pouches that contain the "cook-in-bag" frozen foods should also be pierced once to permit steam to escape during cooking.

Avoid home canning in a microwave oven. The oven is not designed to permit proper canning. Canning is better left to proven methods. Do not severely overcook foods—it may result in a fire. Small quantities of food with low moisture content can burn, dry out, or ignite if cooked too long.

Do not overcook potatoes. When properly done, potatoes will feel firm to the touch, but can easily be pierced with a fork and, when squeezed slightly, the center will seem to collapse. However, if extremely overcooked, a potato can severely dehydrate, carbonize and, eventually, reach a flashpoint and ignite.

IN CASE OF FIRE INSIDE OF AN OVEN CAVITY, UNPLUG THE OVEN AND KEEP THE OVEN DOOR CLOSED.

Heated liquids can erupt, boil over, and cause severe burns. Hot liquids that appear dormant while being removed from the oven can suddenly erupt and boil over—a consequence of superheating. Superheated liquids are capriciously at or above the boiling point, but without being disturbed show no signs of boiling. Removing the seething liquid may provide the vibration needed for a scalding eruption. Superheating can be prevented by stirring the liquids *before* heating them,

or by pouring in another ingredient, which mixes air with the liquid thus preventing the fulminate phenomenon from occurring.

Cooking Utensils

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A customer can use cookware made from glass, plastic, or paper. There are a variety of heat-tempered, oven-proofed clear glass utensils which are available for use in microwave ovens. Only plastics which hold their shape in the presence of heat should be used. Microwaves do not melt plastic, however conducted heat from the food contained within the plastic can distort, melt, or otherwise damage plastic cookware. Paper products may be used where directed. Paper plates should not be used with foods of high moisture content unless the paper has a plastic coating. Paper toweling may be used to cover foods that splatter or to absorb grease. Utensils that contain metal in the composition or the decoration should not be used in a microwave oven. Dinnerware or glass cookware with a painted edge, metal trim, or metal attachment should not be used. If the body or any portion of a utensil becomes unusually hot during a short period of time in the oven, the utensil should be considered as unsuitable for microwave cooking. If arcing occurs, turn off the oven and check the cookware carefully for metal.

Metals and Other Materials

Generally, metal cookware should not be used in a microwave oven. The only variance from this is the use of metal foil, which should be used only as directed. Tin foil (or aluminum foil) in small pieces may be used to cover certain tender areas, such as poultry wings, to block the microwaves and thus prevent overcooking. The foil used should never be closer than one inch to the side walls, door, or any metal surface within the cooking cavity.

Wooden bowls, spoons, or boards should *not* be used because they may become dried out and split or crack.

Before using any questionable material, consult the owner's guide for the proper usage.

Glossary

Appendix IV

AC VOLTAGE: An electric current that reverses its direction regularly and continually, thus it is Alternating Current.

AMPERAGE: The strength of an electric current measured in *amperes.* One ampere is the amount of current that flows through one ohm of resistance with one volt applied.

AMPLITUDE: The maximum instantaneous value of an alternating wave of voltage or current, measured from a reference line to either a maximum positive value or maximum negative value.

ANALOG: A variable which remains similar to another variable in proportional relationships over a specified range.

ANODE: The positive electrode in an electrochemical device. In a magnetron tube, the *anode* is usually the outer casting and is at ground potential.

ANODIZE: A process that electrolytically produces an insulating oxide film on a conducting surface.

ANTENNA PIN: See tuning stub.

BIAS: A DC voltage applied to the control electrode of an electronic device to establish the desired operating point.

CAPACITANCE: The property of a capacitor that determines how much charge can be stored in it for a given potential difference across its terminals. The basic unit is the *farad.* However, the small *microfarad* unit is more commonly used: abbreviated *MFD.*

CATHODE: The general name for any negative electrode. In a magnetron tube, the *cathode* is centered within the anode and at high negative voltage potential.

CAVITY RESONATOR: A space totally enclosed by a metallic conductor and supplied with energy in such a way that it becomes a source of electromagnetic oscillations. In a microwave oven, the food compartment is a *resonant cavity.*

CHOKE: (1) An inductance (usually a coil) used in a circuit to impede the flow of

pulsed DC or AC without appreciably affecting the flow of DC. (2) A groove, channel, or other discontinuity that is dimensioned so as to reflect guided electromagnetic waves of a certain frequency range.

CONVECTION: The transmission of heat by the mass movement of the heated air.

CORE: A magnetic material that affords an easy path for magnetic lines of flux.

CUMULATIVE EFFECT: Many exposures to small doses add up to a large dose.

CURRENT LIMITER: A protective device, used in some two-fold applications as a fuse, that is designed to limit current flow in high-amperage circuits.

CYCLE: One complete positive and one complete negative alternation of a current or voltage.

DC VOLTAGE: An electric current that flows in one direction only, thus it is Direct Current.

DIELECTRIC: A material of poor conductivity that serves as an insulator, usually in reference to the insulating material between the plates of a capacitor. The *dielectric* separates the metal plates electrically, stores an electric charge, and undergoes polarization when subjected to an electric field.

DIFFERENCE OF POTENTIAL: The voltage existing between two points. If a circuit is established between the two points, a flow of electrons will result.

DIRECTLY HEATED CATHODE: A wire or filament that is designed to emit electrons when an electric current flows through it. The current heats the filament to the point where electrons are emitted.

DUMMY LOAD: A device used at the end of a waveguide to convert transmitted energy into heat so no energy is radiated outward or reflected back.

DUTY CYCLE: In a magnetron tube: The ratio of oscillating time to total time.

ELECTRODE: The terminal at which electricity passes from one medium into another, such as in a humidity sensor unit where the current leaves or returns to the semi-conducting ceramic compound.

ELECTROMAGNETIC RADIATION: The process in which waves of electromagnetic energy is sent out into space.

ELECTROMAGNETIC WAVE: A wave of energy propagated by the combined interaction of electric and magnetic fields that are traveling at right angles to each other, and to the direction of travel.

ELECTRON: A high-speed, negatively-charged particle that revolves around the nucleus, and forms a part, of all atoms.

ELECTROSTATIC: Pertaining to electricity at rest or to stationary electricity (static electricity), such as a *static charge* on an object.

FERRITE: A ferric oxide material that has both magnetic properties and a high resistance to current flow. The high electrical resistivity makes any current losses extremely low at high frequencies.

FET: Field-effect transistor.

FILAMENT: A resistance wire or ribbon that, in a magnetron tube, is also the cathode. When an electric current flows through it, the filament heats up to a temperature by which electrons are liberated, thus the filament produces free (or floating) electrons.

FLUX: In electrical or electromagnetic devices, a general term used to designate collectively all the electric or magnetic lines of force in a given region.

FREQUENCY: The number of times a wave makes one full cycle in one second of time. Usually expressed in *hertz* (Hz).

FULL-WAVE RECTIFIER: A circuit which uses both positive and negative alternations of an alternating current to produce a direct current.

GROUND: Zero potential with respect to the ground or earth. A metallic connection with the earth is used to establish ground potential, and to provide a common return to a point of zero potential. When connected to a properly grounded and polarized circuit, the chassis of a microwave oven is at ground potential.

HALF-WAVE RECTIFIER: A circuit that uses only ½ of each cycle to change AC to pulsating DC.

HARMONIC FREQUENCIES: Integral multiples of a primary frequency.

HEATER: See filament.

HEATSINK: A metal device that is clamped onto a heat-sensitive component for the purpose of diverting and dissipating soldering iron heat.

HENRY: The basic unit of inductance.

HERTZ: Cycles per second.

IC: Integrated Circuit. An interconnected network of electrochemical elements integrated into a tiny electronic circuit that performs at least one, and usually more, logic functions.

IMPEDANCE: A combination of resistance and reactance that offers opposition to the flow of current in a circuit. Impedance is usually expressed in ohms.

INDUCTANCE: The property of a circuit that causes a magnetic field to be produced which tends to oppose any change in the existing current flow. The basic unit of inductance is the *henry*.

INDUCTION: The act or process by which a voltage is produced by the relative motion of a magnetic field across a conductor. Or, the process by which a magnetic field is produced by the variance of an electric current through a conductor.

INFINITE OHMS: An incalculably high amount of electrical resistance; essentially an open circuit.

INSULATOR: An implement having high electrical resistance, used for supporting, surrounding, or separating conductors so as to prevent undesired current flow between the conductors or to other objects.

INTERFACE CIRCUITRY: Serves to link the otherwise incompatible high-impedance circuits of the microprocessor and the high-potential circuits of external components.

IONIZING: The dislodging of orbital electrons from atoms, creating electrically charged, highly unstable, and chemically reactive atoms, called ions, which are damaging to living cells.

LAYER SHORT: A condition in a transformer in which two adjacent windings come into abnormal contact with each other through the insulating layer.

LC CIRCUIT: A circuit containing inductive reactance and capacitive reactance.

LCD: Liquid Crystal Display. A digital display which utilizes a liquid crystal material to form digits and characters without generating any light. The liquid crystal material separates and is sealed-in by two sheets of glass, one of which has character-forming segments etched into it and serves as the viewing side. When voltage is applied to the electrodes that extend from each of the etched segments, the liquid adjacent to the segments changes tone (usually darkens), thus forming visible characters.

LED: Light-Emitting Diode. A semi-conductor diode that efficiently converts electric signals into light, and thus glows when current passes through it. In microwave ovens, LEDs are generally used for control panel displays and indicators.

LOAD: An object or device that consumes electrical energy, and thus changes the energy into another form. Food products change microwave energy into heat energy.

MEGOHM: One million ohms.

MICRO: A prefix meaning one-millionth.

MICROFARAD: One millionth of a farad; abbreviated *MFD.*

MICROPROCESSOR: A microprocessor incorporates various computer functions such as memory, calculation, data processing, and control into a tiny silicone chip. The microprocessor receives input and generates output signals in a sequence of logic which is either externally programmed or internally preprogrammed.

MILLI: A prefix meaning 1/1000.

MILLIWATT: 1/1000 of a watt of electricity.

MODULATION/DEMODULATION: Modulation is the ability to impress intelligence upon a transmission medium. A transmission medium may be described as radio waves, light or infrared beams, wire lines, sound, or other communication systems. The characteristics (intelligence) of one waveform are impressed onto a second waveform by varying the frequency, amplitude, phase, or other characteristics of the second waveform. Demodulation is the removal or recovery of the intelligence from the medium.

MOSFET: Metal oxide semiconductor field-effect transistor.

NEGATIVE CHARGE: An electrical medium which has an excess of electrons, thus having the ability to repel electrons.

NEGATIVE TEMPERATURE COEFFICIENT: A factor which expresses the amount of reduction in the value of a quantity relative to ambient temperature. For example, a given decrease in a resistance for each degree of increase in temperature.

OHM: The basic unit of resistance. One volt will cause one ampere of current to flow through one ohm of resistance.

OPEN CIRCUIT: A circuit which does not provide a complete path for the flow of current.

OPTO-COUPLER: See *photo-coupler.*

PARALLEL CIRCUIT: Two or more electrical devices connected to the same pair of terminals so more than one current path is available. Current flows through each device in the parallel circuit.

PHASE: The relationship in time and polarity between two waves. A *phase difference* results when one wave leads or lags another.

PHOTO-COUPLER: An isolated coupling device which, when energized by an input, sends a signal to a semiconductor switching device, such as an SCR.

POLARITY: The relative condition of being positive or negative with respect to a given potential.

POLARIZED RECEPTACLE: A receptacle designed to ensure that the neutral side of an AC line is always connected to the neutral side of an appliance, such as a microwave oven.

POSITIVE CHARGE: An electrical medium which has become deficient in electrons, thus having the ability to attract electrons.

POTENTIAL: The amount of charge held by a body as compared to another point or body. A difference in voltage potential between two connected points results in current flow between the two points. The difference in potential is measured in volts.

PROTONS: One of the fundamental particles of the nucleus of an atom and carries a unitary positive charge.

RADIATION: The process of emitting radiant energy in the form of waves or particles.

RC CIRCUIT: A circuit having a resistance and a capacitance in series.

RESONANCE: The condition produced when the frequency of vibrations are the same as the natural frequency of a cavity. The cavity is sympathetic to the frequency, thus the vibrations reinforce each other.

RESONANT CIRCUIT: (explained in detail in part 3) A coil and capacitor connected in parallel form a capacitive-inductive resonant circuit. Energy supplied to the circuit will charge up the capacitor. When the energy supply is removed, the capacitor discharges through the coil. Current flow through the coil causes a magnetic field to develop around coil. The magnetic field then collapses around the coil, self-inducing a current flow in the opposite direction, which then charges the capacitor in the opposite polarity. Consequently, the capacitor discharges again, starting the process all over.

SCR: A semiconductor device that is controlled by a gate signal. Normally the SCR acts as an open switch, but upon application of an appropriate gate signal to its gate terminal, the SCR instantly switches to a conducting state, becoming as a closed switch.

SERIES CIRCUIT: An arrangement of electrical devices that are connected so that the total current must flow through all the devices in order to complete the circuit.

SHORT CIRCUIT: A low resistance (usually zero ohms) connection across a voltage source or between two points in a circuit that are of different electrical potential. A short circuit usually results in excessive and possibly damaging current flow.

SOLENOID: An electromagnetic coil that contains a movable plunger.

STANDING WAVE: The distribution of waves in a reflective enclosure in which the waves coincide at maximum and minimum points on a resultant wave that appears to stand still.

SUBSONIC: Soundwaves beyond the lower limits of human audibility.

SYNTHESIZER: See *Voice Synthesizer*.

TERMINAL: (1) A point to which electrical connections can be made. (2) The electrical input or output of a circuit or component.

TRIGGER: A short pulse, either positive or negative, which can be used to cause an electrical function to occur.

TUNING STUB: A rod, screw, or post of conductive material that projects into a waveguide for one or more of the following purposes: impedance matching, producing desired phase relationships, or to minimize reflected energy.

ULTRASONIC: Pertaining to sound waves having a frequency that is generally above the limits of human audibility.

VOICE SYNTHESIZER: An instrument that simulates speech by digital control. The synthesizer assembles and digitizes the various elements of a dialect, so the appropriate inflections and other speech characteristics of any language can be simulated.

VOLT: The unit of electrical potential (electromotive force or electrical pressure). One volt is the pressure required to send one ampere of current through one ohm of resistance.

VOLTAGE: Voltage is the force (or pressure) that causes current to flow through a conductor. The voltage of a circuit is the greatest effective difference of potential between any two conductors of a circuit.

VOLTAGE DROP: Ratio of voltage (or electrical pressure) lost (or dropped) across a specified load as a result of forcing current flow through that load.

WATT: The practical unit of electric power. In a DC circuit, one watt of power is used when one ampere of current flows through a resistance of one ohm.

WAVEGUIDE: A rectangular, circular, or elliptical hollow metal tube designed to transport electromagnetic energy through its interior from one point to another.

WAVELENGTH: (1) The distance in space occupied by one cycle of an electromagnetic wave at any given instant. (2) The distance a wave travels during one cycle.

Manufacturer's Addresses

Appendix V

Many manufacturers are represented through regional distributors or dealers. Others operate provincially through regional offices. In each case, the appropriate regional center to contact for parts, service, technical or customer assistance, and other information, can be ascertained from the main corporate offices. In some instances, several *brand names* are affiliated with one parent corporation, these names are italicized and parenthesized under the main corporate contact.

CORPORATE CONTACTS

A

Amana Refrigeration, Inc.
Amana, Iowa 52204
Telephone (319) 622-5511

B

Brother International Corporation
8 Corporate Place
Piscataway, New Jersey 00854
Telephone (201) 981-0300

D

Daewoo Electronics Corp. of America
(Daytron, Portland)
100 Daewoo Place
Carlstadt, New Jersey 07072
Telephone (201) 935-8700

E

Emerson Radio Corporation
One Emerson Lane
North Bergen, New Jersey 07047
Telephone (201) 854-4800

G

General Electric Company
(Hotpoint)
Appliance Park
Louisville, Kentucky 40225
Telephone (502) 452-4311

Gerald Industries, Inc.
3505 N.W. 112th Street
Miami, Florida 33167
(305) 688-6634

Goldstar Electronics Int'l, Inc.
(KMC)
1050 Wall Street, West (2nd Floor)
Lyndhurst, New Jersey 07071
Telephone (201) 460-8870

H

Hitachi Sales Corp. of America
401 W. Artesia Blvd.
Compton, CA 90220
Telephone (213) 537-8383

Hobart Corporation
Troy, Ohio 45374
Telephone (513) 332-3000
(513) 335-7171

Holaday Industries, Inc.
14825 Martin Drive
Eden Prairie, Minnesota 55344
Telephone: (612) 934-4920
Telex: 29+0922, FAX: 612/934-3604

K

Kawasho Factory Service
747 Clinton St.
Buffalo, New York 14210
Telephone (716) 845-6060

L

Litton Microwave Cooking Products
P.O. Box 1965
4450 Mendenhall Road South
Memphis, TN 38101-9990
Telephone (901) 366-3136

M

Matsushita Services Company
(Panasonic, Quasar)
50 Meadowland Parkway
Secaucus, New Jersey 07094
Telephone (201) 348-7522/7523

Maycor Appliance Parts & Service Co.
(Admiral, Hardwick, Jenn-Air, Magic Chef, Maytag, Norge)
740 King Edward Ave.
Cleveland, TN 37311
Telephone (615) 472-3333

N

NARDA Microwave Corporation
Publications Department
435 Morland Road
Hauppauge, New York 11788
Telephone: (516) 231-1700
TWX: 510-221-1867
FAX: 416-231-1711 London, Ontario

Norelco Service, Inc.
30-10 Review Ave.
Long Island City, NY 11101
Telephone (718) 687-0718

R

Robinair Division—Service Products
Sealed Power Corporation
Robinair Way
Montpelier, Ohio 43543-0193
Telephone 419-485-5561

Roper Sales Corporation
1905 West Court Street
P.O. Box 867
Kankakee, Illinois 60901
Telephone (815) 937-6000

S

Sampo Corporation of America
5550 Peachtree Industrial Blvd.
Norcross, Georgia 30071
(404) 449-6220

Samsung Electronics of America, Inc.
(Conair, Hamilton Beach)
301 Mayhill Street
Saddlebrook, New Jersey 07662
Telephone (201) 587-9600

Sanyo Electric, Inc.
SFS Corporation
200 Riser Road
Little Ferry, New Jersey 07643
Telephone (201) 641-2333

Sharp Electronics Corporation
Sharp Plaza
Mahwah, New Jersey 07430
Telephone (201) 529-8200

Simpson Electric Company
Publications Department
853 Dundee Ave.
Elgin, Illinois 60120-3090
Telephone: (312) 697-2260
Telex: 72-2416 Cable: SIMELCO
In Canada: Bach-Simpson, Ltd.
In England: Mack-Simpson (U.K.) Ltd.
Wadebridge, Cornwall
In India: Rutton-Simpson Private, Ltd.
International House, Bombay-Agra Road
Vikhroli, Bombay.

Sunbeam Appliance Service Co.
P.O. Box 1570
1333 Butterfield Road
Downers Grove, Illinois 60515
Telephone (312) 719-5000

T

Thermador/Waste King
5119 District Blvd.
Los Angeles, California 90040
Telephone (213) 562-1133

Toshiba America Inc.
82 Totowa Rd.
Wayne, New Jersey 07470
(201) 628-8000

Triplett Corporation
Publications Department
1 Triplett Drive
Bluffton, Ohio 45817
Telephone 800-328-2677

V

VACO Products Company
Publications Department
10 Skokie Blvd.
Northbrook, Illinois 60062
Cable: VACOPRO, TWX 910 686 0658

W

Whirlpool Corporation
6585 Crescent Drive, N.E.
Norcross, Georgia 20071
Telephone (404) 449-4375

White Consolidated Industries
(Frigidaire, Gibson, Kelvinator, O'Keefe & Merrit, Tappan, White-Westinghouse)
300 Phillipi Road
P.O. Box 182056
Columbus, Ohio 43218
Telephone (614) 272-4100

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